

EXPLORE



Regional Ocean Exploration Workshops

Summary Report: Volume I

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Regional Ocean Exploration Workshops Summary Report: Volume I

This report has been prepared for the National Oceanic and Atmospheric Administration (NOAA) Office of Ocean Exploration by Mitretek Systems, Inc. Mitretek is a nonprofit corporation chartered to work in the public interest and performs under a directed award contract with NOAA to provide objective, conflict-free advice, especially regarding information technology (IT) investment decision-making, program management, and budget and strategy formulation. This document is provided in accordance with and fulfillment of the Modification 1 Deliverable 3 requirement in Task 20 of the Mitretek contract with NOAA.

1 Introduction

During a seven-week period extending from late February through mid-April 2002, NOAA's Office of Ocean Exploration (OE) conducted eight regional workshops at locations representing the diverse geographic interests of the oceanographic community. These workshops were conceived and designed to solicit the input of informed constituencies in order to refine the strategic priorities of the NOAA national Ocean Exploration Program while in its early stages of execution.

On behalf of NOAA, OE coordinates and conducts missions to explore regions of the oceans for the purposes of discovery and science. This OE program is currently operating under the guidance of the October 2000 Report of the President's Panel on Ocean Exploration, *Discovering Earth's Final Frontier: A U.S. Strategy for Ocean Exploration* (hereafter referred to as the *Frontier Report*).¹ The *Frontier Report* identified diverse and important goals and objectives that constitute a national strategy of ocean exploration at a recommended level of funding of approximately \$75 million (M) per year. The NOAA OE program currently has a \$14M annual budget and seeks to adopt the goals of the *Frontier Report* in the most productive way. To efficiently address these goals, OE produced a strategic framework² for the program that recognized the need for input from a broad community of stakeholders in order to provide focus for a synchronized OE Program Strategic Plan.

With the assistance of regional NOAA personnel, OE identified representatives to help define program priorities from the ocean exploration, science, education, technical, engineering, and communications professions, including participants from the federal, state, and tribal governments, plus members of academia, industry, and organizations that work with marine science and information. A representative cross-section of these contacts offered their time and energy as participants in each of the eight regional workshops.

This report provides an overview of the workshop process, presents information collected during the workshops, and presents the initial analysis of workshop results. Section 2 describes the design, development, and implementation of the workshop process. Section 3 provides results of the regional workshops and identifies common exploration needs categories, approaches, and related benefits, and a discussion centered on each of the eight workshop regions. Section 4 relates the workshop results to guidance in the *Frontier Report*, provides an assessment of capital asset needs that includes ship capacity and technology development, summarizes benefits realized from the exploration activities, presents potential partnerships, and addresses other issues related to ocean exploration priorities. Supporting data and information are included Volume II.

This volume reflects inputs provided by participants of the regional ocean exploration workshops introduced in Section 1. It is intended to accurately and collectively represent the information provided by these participants. During the course of analysis and quality control of these data, duplicative items have been combined, sensitive references to organizations and individuals have been removed, and consistency in presenting the information from each of the workshops has been sought. Every attempt has been made to ensure the information is complete. For reference purposes, the raw workshop data used to develop this volume are in Volume II.

Readers should recognize that the information contained herein represents the perspectives of the workshop participants only, augmented by additional comments received separately from invitees who were unable to attend. Appendix A provides contact information on workshop attendees, while Volume II contains the complete

invitation list for the regional workshops. The exploration needs, approaches, geographic areas of interest, technology needs, and potential partners listed in this report are based solely on the information provided by participants. No program priorities among identified needs are implied. The reader may conclude with confidence that the actual cross-section of ocean exploration stakeholders, both in the U.S. and abroad, extends significantly beyond the workshop participants. The information in this report—while representative of a large number of ocean exploration stakeholder needs—will be augmented with many additional needs, approaches, geographic interest areas, and partnerships as public and private involvement in NOAA’s ocean exploration initiatives expands and evolves.

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2 Workshop Process Overview

This section describes the progression of the workshop process design and development. It also describes the conduct of the workshops and adjustments to the process during the course of the workshops based on participant feedback.

2.1 Workshop Development

The NOAA corporate intention to seek the guidance of a broad community of ocean exploration stakeholders in order to refine program priorities within the context of the *Frontier Report* was originally proposed by the Acting Administrator of NOAA in testimony before the U.S. Congress in July 2001.³ In January 2002, the Director of OE solicited the assistance of regional National Undersea Research Centers (NURCs) and the National Marine Sanctuaries System (NMSS)⁴ in identifying an appropriate, representative cross-section of ocean exploration stakeholders within each region. The complete list of invitees, including the identity of those who attended the workshops, is included in Volume II. Local points of contact for providing administrative and logistical support were also identified. Stakeholders subsequently received invitations from OE to participate in the workshop that would be hosted within their region. These invitations provided background information on OE, directed attention to the guidance within the *Frontier Report*, and requested participant input within the planned, facilitated workshop sessions to address the following questions:

- What do we not know about the oceans and specific ocean regions?
- What will it take to gain this knowledge (in terms of technologies, deployable assets, and costs)?
- In what order or priority should these be addressed?
- What are the regional assets and who are potential partners?

During this preparatory phase, OE enlisted the assistance of facilitators with subject matter expertise from Mitretek to help ensure unbiased objectivity in developing the process and during the conduct of the workshops. The regional areas of emphasis, locations, dates, and local points of contact for each of the workshops are listed in Table 2-1. OE also created an email address to collect input from invitees who desired to participate in the process but were unable to attend a particular workshop.

Table 2-1. Regional OE Workshops

Region	Dates	Location	Local Point of Contact
Caribbean	February 25-26	Rosenstiel School of Marine & Atmospheric Science (RSMAS), Univ. of Miami, Miami, Florida	Dinah Berry
Gulf of Mexico	February 28 – March 1	Mississippi Mineral Resources Institute, Univ. of Mississippi, Oxford, Mississippi	Robin Buchannon Nancy Roberts
Hawaii	March 12-13	Ala Moana Hotel, Honolulu, Hawaii	Karynne Morgan
Alaska	March 18-19	Captain Cook Hotel, Anchorage, Alaska	Jennifer Reynolds Dana Kapla
West Coast	March 21-22	Monterey Bay Aquarium Research Institute (MBARI), Moss Landing, California	Kelly Newton Cyndi Stubbs
Atlantic North	March 27-28	University of Connecticut (Avery Point), Groton, Connecticut	Chris Marceau
Great Lakes	April 4-5	Milwaukee County War Memorial Center, Milwaukee, Wisconsin	Joni Jackson Smith Anne Wright
Atlantic South	April 10-11	National Center for Coastal Environmental Health & Biomolecular Research (CCEHBR), Charleston, South Carolina	Debbie Lawson Karen Lawrence

Gary Mineart and Mike Ciarametaro of Mitretek designed the two-day workshop structure with guidance from Tom Goodspeed and Tim Culliton of the National Ocean Service (NOS) Special Projects Division and Joanne Flanders of OE. The process consisted of two phases of information gathering from workshop participants. Two breakout groups (eight to fifteen people each) were designed for the collection of information in both phases. Objective areas based on the goals and objectives contained in the *Frontier Report* were developed and used to focus the direction of the breakout group participants. These objective areas are described in Table 2-2. Although these objective areas tended to focus on areas within U.S. jurisdiction such as the Economic Exclusion Zone (EEZ), the process was designed to accommodate perceived needs beyond boundaries associated with current paradigms.

Table 2-2. OE Workshop Objective Areas

Observation and Mapping	
Summary:	Observation and mapping of the physical, geological, biological, chemical, and archeological aspects of the ocean, such that the U.S. knowledge base is capable of supporting the large demand for this information from policy makers, regulators, commercial ventures, researchers, and educators
Elements:	<ul style="list-style-type: none"> • Find and systematically explore dozens of new archeological sites • Discover both living and nonliving resources and their identity, location, and abundance principally within the EEZ and continental margins • Discover thousands of undescribed species • Find new ecosystems and describe communities of organisms displaying novel relationships with their physical, chemical, and geological environments • Map the ridges, canyons, faults, and other key features of the EEZ and continental margins that have scientific or cultural importance
Ocean Dynamics and Interactions	
Summary:	Exploration of ocean dynamics and interactions at new scales, such that our understanding of the complex interactions in the living ocean supports our need for stewardship of this vital component of the planet's life support system
Elements:	<ul style="list-style-type: none"> • Explore the variability of the ocean's interior and the earth beneath it • Discover dozens of new oceanographic features changing over spatial scales from 10 to 10,000 kilometers, and temporal scales from picoseconds to millennia; including the ocean's interaction with the atmosphere and as a key component of the global hydrological cycle • Discover unexpected changes in temperature, salinity, photosynthesis, and ocean circulation over a wide range of time scales through sensing of the ocean's surface • Explore the connection of living and nonliving systems in the ocean and coastal zones by unraveling dozens of biological, geological, chemical, and physical processes affecting the interactions among species and the cycling of organic materials
Development of New Technologies Reaching out to Stakeholders in New Ways	
Summary:	<p>Developing new sensors and systems for ocean exploration, so as to regain U.S. leadership in marine technology</p> <p>Reaching out in new ways to stakeholders, to improve the literacy of learners of all ages with respect to ocean issues</p>
Elements:	<ul style="list-style-type: none"> • Invent, build, and adapt the wide array of tools, including remote sensors and in-situ capabilities, necessary for measuring, mapping, and exploring the physical, geological, chemical, and biological parameters of the ocean • Create new concepts and methods for viewing the whole ocean through time, from anywhere • Establish the ability to broadcast ocean expeditions to reach school districts in the nation • Develop new technologies that bring scientists and explorers into formal and informal educational settings, and students, educators, and the general public into the field • Allow petroleum, fisheries, and biomedical industries to make hundreds of discoveries of new materials, pharmaceuticals, and enzymes using the knowledge gained from ocean exploration

The first phase of the workshop process was designed to focus on the identification of ocean exploration needs within candidate regions of interest based on the perspectives of the workshop participants. Activities during this phase included obtaining a description of each need, reasons that justified emphasis on each need, technologies that could be

applied, and specific geographic areas of emphasis matched against each need. This first phase concluded with an exercise by participants designed to link related needs, identify within the developed needs those that participants commonly felt warranted some level of emphasis, and select the order that the needs would be addressed during the second phase of the workshop.

This second phase sought potential approaches for satisfying the ocean exploration needs identified during the first phase. For each potential approach, workshop participants identified enabling technologies that existed or needed to be developed, a candidate list of regional stakeholders that were considered potential partners for each line item, key benefits that were expected to be realized, and a qualitative measure of the implementation feasibility.⁵

The workshop design included a plenary review of breakout group results following both phases and opportunities for participant feedback to the facilitators. The workshop facilitation team developed and produced large hardcopy plots of the worksheets that were used to gather information in the breakout sessions, with each leading worksheet including an example of the data to be collected. Additional large plots were produced in order to display the workshop objectives, breakout group objective areas, and guiding principles for participant conduct in the plenary meeting room and in each breakout room. A total of 320 large plots were produced to support the eight workshops. Additionally, NOAA nautical charts covering each regional area of interest were provided for use by the workshop participants.

2.2 Implementation

The facilitation team initially executed the workshop process in Miami, Florida for the Caribbean region (Figures 2-1 and 2-2). Information captured on large hardcopy plots during the breakout group sessions was also recorded in real-time on electronic worksheets by facilitation team recorders using laptop computers; these worksheets were used by participants to brief breakout group session results. These worksheets were also used by the facilitation team to retain a record of the information produced by the

workshop, to produce summaries of the first day's results for use during the second phase of the workshop, and to provide participants with a raw copy of results for their retention.



Figure 2-1. A breakout group selects common interests as part of an exercise during the Caribbean region workshop (*image courtesy of Amy Sheridan*)

Three modifications to the process were implemented as a result of constructive feedback provided by participants at the initial workshop. Initially, time had been devoted to the second phase at the end of the first day of the workshop. Since the conclusion of the first phase plenary session represented a natural break in the process, this point became the new conclusion of the first workshop day and the needs identification phase was expanded slightly to fill the time. The participants elected to link exploration needs into related groups for the second phase, which eliminated need for the originally planned time on the first day to commence the second phase of the workshop. The second modification was a transition during the second phase from a discussion of cost ranges for each approach to the qualitative measure of feasibility discussed earlier. This modification was driven by the difficulty in approximating cost ranges for exploration approaches that incorporated a significant amount of new technology and a general

reluctance on the part of many workshop participants to offer cost estimates. The third process modification was made due to the emphasis placed on identification of applicable target locations for exploration activities during the first phase of the process, negating the need to reemphasize locations for specific approaches during the second phase. In its place, the facilitators elicited key benefits resulting from the potential satisfaction of applicable ocean exploration needs.



Figure 2-2. Dr. Jerald Alt of RSMAS presents breakout group results in plenary session at the Caribbean region workshop (*image courtesy of Amy Sheridan*)

With the exception of these modifications, the workshop process remained relatively stable throughout the eight regions. The agenda was adjusted slightly as necessary to incorporate the logistical needs of local host site personnel. One observation shared by facilitators after the first few workshops was the recurrence of similar approach techniques and suites of equipment identified by participants to meet a variety of exploration needs. To streamline the second phase of the process, the facilitators began to offer these similar techniques, equipment suites, and collaborators as “standard packages” or “standard partners” to which the participants could add or subtract elements as deemed

appropriate. This practice allowed each breakout group to address a greater number of exploration needs during this second phase. This process is discussed in greater detail in Section 3.

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3 Workshop Results

This section provides information derived from the results of the eight workshops. Exploration needs categories are provided that have been consolidated and standardized from the raw workshop data. Categorized exploration needs resulting from each workshop are listed and include descriptive information, candidate locations for exploration, enabling technologies, and potential partners. Charts showing the general location of candidate exploration targets also accompany these data.

3.1 Exploration Needs Categories

The results from the workshop needs identification and exploration approach phases represent contributions from participants totaling over 300 person-days of effort. A suitable organization of this large amount of information was required in order to provide a means for analyzing and using the collected data. Additionally, these data covered a wide range of disciplines. Subject matter included all fields of oceanography and other areas related to geology, biology, chemistry, and archeology. Technologies from basic mechanical equipment to complex instrumentation were also discussed. The geographic distribution of the workshops and the broad scope of scientific expertise in attendance led to a large number of diverse exploration initiatives.

To provide the necessary organization, data were summarized by dividing the information into exploration needs categories based upon dominant subjects within the information. These categories are listed alphabetically in Table 3-1 with an accompanying definition for each category. They are used throughout this report as an organizational basis for the workshop results and have not been subjected to any prioritization scheme. The volume of ocean exploration needs described by each category varies significantly from category to category. An emphasis on the exploration of unique environments and the constituents within those environments is evident in the list of categories, illustrated by the variety of marine ecosystems included as individual items.

Table 3-1. Exploration Needs Categories

Need Category	Definition
Archeology	Exploration of submerged material remains represented by fossils, relics, wrecks, remains, and artifacts in the study of humans and their history, heritage, activities, or impacts
Artificial Habitats	Man-made objects that intentionally or serendipitously serve as habitats for marine biota
Benthic Environment	The ocean bottom and sub-bottom including permanent communities of organisms and their interactions
Boundary Fluxes - Air/Sea	The exchange of energy and matter between the air and sea environments
Boundary Fluxes - Basins	The exchange of energy and matter between the bottom boundary of the ocean and the overlying waters
Corals - Deep Water	Corals and coral reefs located below 200 meters depth
Corals - Shallow Water	Corals and coral reefs located above 200 meters depth
Currents & Water Masses	The advection and convection of the ocean, its physical properties, and its effects on water masses, boundaries, ecosystems, and biotic and abiotic constituents
Ecosystems - General	Interactions of all organisms with and within their environments, including the inventory and mapping of these constituents and their environments
Ecosystems - Abrupt Topography (subcategories listed below)	Ecosystems influenced by rapidly changing and variable geomorphologic features
Arcs	The long broad elevation that rises from the sea floor around ocean basins
Canyons	A submarine valley with relatively steep slopes and progressive deepening in a direction away from shore
Channels / Straits	A waterway or strip of water that connects two larger bodies of water
Fjords	A narrow steep inlet from the sea excavated by glaciation
Glacier tongues	The projection of a glacier seaward, usually afloat
Karst / Ring Depressions	Areas of characterized by ravines, sinks, caverns and depressions possibly arising from underground streams and currents
Seamounts/Ridges	Unusually pronounced elevation rising 900 meters or more from the ocean bottom
Trenches	A long, narrow, and steep seafloor depression
Ecosystem - Banks & Basins	Ecosystems on or near the ocean floor that are at a depth greater than 2000 meters
Ecosystem - Extreme Environments - Sea Ice	Ecosystems in the marginal ice zone, under sea ice, and adjoining high-latitude waters
Ecosystem - Extreme Environments - Vents, Seeps & Volcanoes	Ecosystems near geologically active bottom features that are characterized by immoderate, intense physical, chemical, biological, and geological conditions
Ecosystem - Caves	Ecosystems in enclosed, confined underwater areas
Ecosystem - Lakes	Ecosystems in freshwater lakes
Ecosystem - Shoreline to Ledges	Ecosystems located in the regions between the coast and the edge of the continental shelf

Need Category	Definition
Ecosystem - Slopes	Ecosystems located in the regions between ocean basins and the continental shelf
Episodic Events	Significant events of regular or irregular temporal frequency occurring in the ocean and inland seas
Geology & Geomorphology	Composition of the ocean bottom, sub-bottom, and the nature and history of the landforms on the ocean bottom and the processes that create them
High Resolution Bathymetry	Mapping of the bottom boundary of the ocean to resolutions on the order of 1 meter in the horizontal and 0.01 meter in the vertical
Human Impacts	Influences and impacts on the ocean environment from humans and human activity
Marine Conservation	The management of marine resources and the identification of candidate areas for regulation and protection
Marine Microorganisms	Marine viruses, bacteria, microplankton, and other biota of a microbial spatial scale and their interactions with the environment
Marine Organisms	Macro-scale marine biota and their biological processes within the context of their natural environment
Ocean Resources - Bioprospecting	The search for valuable chemical compounds and genetic material from oceanic plants, animals and microorganisms
Ocean Resources - Energy & Minerals	Nonliving natural resources in the ocean, including materials that may be exploitable for energy production and those that have significant commercial value
Pelagic Environment	The open ocean environment, its constituents, and the interactions between these constituents and their surroundings
Sound in the Ocean	The application of acoustics to observe the ocean and its inhabitants, including the passive monitoring of biotic, geophysical, or other activity and the active generation and reception of acoustic energy from oceanographic sensors and systems

3.2 Common Approaches

The second phase of the workshop process applied a methodology to collect information on the assets and technologies needed and to add a sense of deliberate process as to how exploration activities would be accomplished. These discussions among the workshop participants allowed the sharing of ideas on how to approach exploration missions, which approaches were most appropriate for certain needs categories, and which assets would be needed to satisfy the identified exploration needs.

A summary of the exploration approaches resulting from these discussions appears in Table 3.2. These approaches and their descriptions were applied to the applicable needs categories during the second phase of the workshops resulting in a clearer definition of the capital assets and related technologies required to satisfy each needs. A discussion of the needs for associated assets and technologies is included in Section 4 of this report.

Table 3-2. Summary of Exploration Approaches

Exploration of Environments		
Approach Name	Approach Description	Applicable Needs Categories
Funnel	A broad-based exploration “survey” of an area of interest, with the resulting data allowing multidisciplinary exploration of increasingly detailed targets within that area	All Categories
Targeted	Use existing data to select specific exploration targets for multidisciplinary explorations	All Categories
Exploration of Dynamic Phenomena		
Approach Name	Approach Description	Applicable Categories
Fixed Position Observation	Use various tools to monitor a fixed exploration area for a designated period of time	Boundary Fluxes - Air/Sea; Boundary Fluxes - Basins; Currents & Water Masses; Ecosystems; Episodic Events; Geology & Geomorphology; Human Impacts; Marine Microorganisms; Marine Organisms; Sound in the Ocean
Mobile Observation	Use of various tools to monitor an area that changes over time. The area of observation changes both passively and actively in response to set of stimuli. Examples of passive response include a drifter in the current or a Critter Cam. Examples of active response include an AUV actively following biota or monitoring the ocean during a hurricane	Boundary Fluxes - Air/Sea; Boundary Fluxes - Basins; Currents & Water Masses; Episodic Events; Geology & Geomorphology; Human Impacts; Marine Microorganisms; Marine Organisms; Sound in the Ocean

3.3 Regional Results

This section provides results from each of the eight regional workshops identified in Table 2-1. The results for each region include a brief summary highlighting unique perspective from that workshop, a table of categorized exploration needs, and charts that display the location of candidate exploration targets identified by workshop participants.

The data in each table are sorted by the exploration needs categories identified in Table 3-1 to enhance their utility. Listed exploration needs and gaps may represent duplicate or similar items generated by breakout groups during the workshops that were combined during analysis. Every attempt was made to preserve the original intent or objective of the participants.

Enabling technology and partnership data incorporate the terminologies of a “standard package” and “standard partners.” These descriptions were developed during the conduct of the workshops and were adopted by facilitators and participants as a mechanism to same time. As data were being gathered, it became clear that many of the exploration needs required the application of similar platforms and suites of equipment in order to satisfy those needs. For example, a standard package might consist of a Class I or II surface vessel with high-resolution acoustic mapping capability, a deep-diving capability (ROV, AUV, or submersible) with imagery/video, sampling, and precise positioning equipment, and education and outreach components. The standard partners descriptor represents groups of regional entities nominated by workshop participants as probable partners and collaborators across many of the regional exploration needs. Each of the tables in this section includes a leading row defining the composition of the standard packages and partners for that region.⁶

The column headings for each of these tables meet the following definitions:

- *ID* – A numeric identifier assigned to the original data, used for tracking and control of individual line items during analysis, and maintained to support further cross referencing
- *Category* – The exploration needs categories presented in Table 3-1
- *Information Need/Gap* – Exploration needs identified by the workshop participants
- *What* – Amplifying descriptive information for the associated exploration need provided by workshop participants
- *Where* – Candidate target areas or sites identified by participants for application of exploration approaches to satisfy the regional needs; identifiable sites within these data are represented on accompanying charts
- *Enabling Technologies* – Application of approaches and desired technologies identified by participants as important contributors to satisfying related exploration needs

- *Partners* – Entities and organizations identified by participants as likely collaborators

The charts that accompany each region's information provide a geographical reference to exploration targets of interest that were identified by workshop participants. These charts are not intended to be an inclusive representation of *all* potential exploration targets of interest in each region, but represent only those locations identified by workshop participants as desired exploration sites. The reader must also recognize that there are a large number of broad, unspecific targets of interest identified by the participants that are not appropriate for inclusion in these charts. Examples include areas such as coastal regions, warm water environments, the deep benthos, and migration routes.

3.4.1 Caribbean Region

The Caribbean Region workshop in Miami represented the initial application of the workshop process among the eight regions. The participants at this workshop added unique value to the regional workshops in their willingness to provide initial feedback to facilitators and make detailed recommendations for improvements to specific portions of the workshop process.

The participants at this workshop placed considerable emphasis on corals and coral reefs, an emphasis not unexpected given the population of unexplored and infrequently monitored coral reefs in the region. A particular theme was the exploration of deep corals and their relationships to fisheries habitats. Discussion centered on determining the health of reefs, performing assessments, and comparing various areas for genetic connectivity.

The group was stimulated by a discussion surrounding marine caves. The participants showed great interest in the exploration of marine caves since it represented an innovative emphasis area that held the promise of considerable discoveries.

This workshop was attended by a large contingent of participants interested in applicable technologies. This background led to significant discussion on the development of new technologies to satisfy ocean exploration needs. Examples included the development of improved imaging technology, new diagnostic and early warning (at the molecular level) devices, miniaturized probes and sensors for discovering bioproducts, and improved mapping tools for night operations.

The participants brought up an interesting question concerning the geographic application of ocean exploration (coastal versus open ocean). It was concluded by the attendees that near-shore exploration should be considered since its applicability would likely be determined by the nature of the information sought in the coastal zone.

Results from the Caribbean workshop are provided in Table 3.3. Regional exploration targets of interest nominated by participants are illustrated in Figure 3-1.

Table 3-3. Caribbean Region Workshop Results

Caribbean Workshop:	
Standard Package⁶: Class I/II Vessel with acoustic mapping; Dive capability (ROV/AUV/ Submersible) with imagery/video and sampling equipment; precise positioning system; surface sampling; bench mounted ocean instruments; good pumped water (rapid input); gas detection system; ADCP; bio-acoustic profiling system; multibeam system; sediment and rock sampling equipment	Standard Partners⁶: U.S. Geological Survey (USGS); National Aeronautics and Space Administration (NASA); NOAA; Coast Guard; Navy; National Geographic; National Science Foundation (NSF); Office of Naval Research (ONR); NURP

Caribbean Workshop Results:						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
55	Archeology	Distribution and nature of submerged archeological resources	For shipwrecks; prehistoric sites; and submerged historical sites determine nature of site and date it	Pan-Caribbean; Mona passage; Southern Bahamas; Florida Keys; Reef areas in general since lots of shipwrecks occur there	Standard Package; Standard diving and archeological techniques; Historical records; Develop ability to properly core and chemically characterize site; GIS to make successful and broad range availability	Standard Partners; National Endowment for the Humanities; Non-governmental organizations (NGO's); private and corporate partners; affinity groups; Discovery Channel; Florida State University; Massachusetts Institute of Technology (MIT); Texas A&M (TAMU); William and Mary; University of Bahamas; Smithsonian
80	Archeology	Exploration in Time	Review historical records; Examine trading patterns; Utilize Genetic Resources; How were the islands colonized?; How people have used (socio economic; cultural) the oceans in past and how has it affected present condition?; Where are we heading?	Pan-Caribbean	Standard archeological techniques; ethnographic data; Zoological techniques	Standard Partners
69	Archeology	Nautical charts from 15th century on - digitize and look at technology and scale to provide historical record; look at evolution of technology	Database - compile current info and map uncharted areas to add to knowledge	US coastal-wide; make this proposal driven to determine 'where'?	Mapping tools and technologies	Standard Partners

Caribbean Workshop Results:						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
78	Boundary Fluxes - Air/Sea	Air/Sea Interactions on the small scale	Document the biological; chemical; and physical processes of the air/sea interface in high resolution over a small area	Caribbean - hurricane source; pan-Caribbean in highly dynamic regions	Develop new sensors to document air/sea interactions on a small scale	Standard Partners
101	Boundary Fluxes - Basins	Impact of fresh water runoff & suspended/dissolved "stuff"	Identify and quantify impact of fresh water runoff & suspended/dissolved matter	All Coastal Regions		Standard Partners
94	Boundary Fluxes - Water Mass	Dynamics of interaction between water masses		Florida Straits; Virgin Islands (VI) - Anegada Passage; loop current production to Florida Straits	Standard Package	Standard Partners
52	Corals - Deep Water	Distribution and status of deep water coral reefs and fish stocks	Collection information on the distribution; taxonomy; abundance; condition; diversity; and size of deep corals and fish stocks;	PR; dry Tortugas; VI; Lang Bank; Shelf bank and wall at VI and PR; Nevassa Island; Columbian Banks; Florida Straits; South end of Cuba; Marquesas; Lots of Places - beyond >20m	Standard Package; remote sensing; technical diving; optics; radio tagging; GIS	Standard Partners; Equipment manufacturers; other commercial operators such as major oil companies; Minerals Management Service (MMS)
53	Corals - Shallow Water	Health and assessment of shallow water coral reefs	"Norms" (coral; fish; biomass) of condition for comparison; One time assessment	Pan-Caribbean shallow water; Marquesas; Tortugas Bank; Islamorada Humps; Riley's Hump	Visual technologies such as SCUBA; hypospectral techniques; aerial photography; develop new diagnostic or early warning technologies - molecular level technologies; remote sensing	Standard Partners; tourism agencies; hotels; hospitality agencies; private foundations
84	Ecosystem - Abrupt Topography	Impacts of underwater topography (Sea mounts, pinnacles, reef edges)		Warm water environments; banks; shelf edge	Standard Package	Standard Partners
86	Ecosystem - Abrupt Topography	Understanding the ecology and oceanography of Florida Straits	Examine source water currents; pollutants; nutrients; and plankton	Florida Straits; VI; Puerto Rico	Standard Package; airborne LIDAR; hyper-/multi-spectral optics (species ID); tracking of tagged fish; human diving technologies; wide bandwidth communications (via LEO SAT); drifters; probes; instrument arrays; fixed ADCP	Standard Partners; state & local agencies; South Florida Ocean Measurement Center (SFOMC); RSMAS; local labs; Immigration and Naturalization Service (INS); Central Intelligence Agency (CIA) Environmental and Societal Issues Center (DESC); U.S. Customs; National Ocean Partnership Program (NOPP); OCEAN.US

Caribbean Workshop Results:						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
92	Ecosystem - Abrupt Topography	Trenches	Exploration in trench region to understand the interactions between abyssal depths and shelf waters (including abiotic/biotic constituents)	Puerto Rico Trench and surrounding area	Standard Package; deep submersible; deep ROV/AUV (multipurpose); surface deployed sampling/analysis devices (cost saving versus deep dive); low light optics; communications	Standard Partners
59	Ecosystem - Banks & Basins	Deep basins	Document biogeography and taxonomy; document physical; chemical; geological; and sediment characteristics	Caribbean basins (4); PR trench	Standard Package; dredging; visual; trawling; trapping; coring.	Standard Partners
57	Ecosystem - Caves	Biodiversity and ecology of marine caves	Characterize and Identify biota using molecular genetics; map; determine chemical; geological; biochemical; and physical characterization; geology; examine for archeological significance	Bermuda; Bahamas; Yucatan; Greater Caribbean	Standard Package; traditional sensors; satellite photos; technical diving; GIS mapping; cave cam; drilling; data processing and visualization tools; remote samplers; coring; smaller tools (bore hole size)	Standard Partners; pharmaceutical industry; biotech; medical manufacturers; equipment manufacturers; U.S. Department of Agriculture (USDA); cosmetic companies; National Institutes of Health (NIH); Sea Grant; National Center for Natural Products Research (NCNPR); Scripps Institution of Oceanography (SIO); Smithsonian; commercial operators such as charter boats; cave divers; fishermen; hunters; taxonomist
58	Ecosystem - Extreme Environment - Vents, Seeps	Find new vents and seeps (includes fresh water seeps)	Document biogeography and taxonomy; Document physical; chemical; geological; and sediment characteristics	Fresh water communities as well as marine; brine pools; Cayman trench; PR trench; any seismically active area	Standard Package; deployment of platforms that stay in place for long term monitoring; thermal mapping; salinity measurements; technical diving in some of the shallower vents	Standard Partners; pharmaceutical industry; biotech; medical manufacturers; equipment manufacturers; USDA; cosmetic companies; NIH; Sea Grant; NCNPR; SIO; Smithsonian; commercial operators such as charter boats, fishermen, hunters; taxonomists
340	Ecosystem - Extreme Environments - Vents, Seeps, & Volcanoes	Kick'em Jenny Volcano	Fully document this active volcano, which is likely to be the next Caribbean island	Kick'em Jenny Volcano (Approximately 4 miles north of Grenada)	Standard Package	Standard Partners

Caribbean Workshop Results:						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
63	Ecosystem - Shorelines to Ledges	Status of fish stocks and habitat on the Islamorada Hump	Collect information on distribution; taxonomy; abundance; condition; and diversity	Islamorada Hump; Florida Keys	Standard Package; advanced diving; passive acoustics	Standard Partners
85	Ecosystem - Shorelines to Ledges	Knowledge of fisheries habitats	Scope and variability of tropic productivity in reef systems	20-200m	Standard Package; develop acoustic techniques for classification (benthic; reef; and water column organisms); airborne LIDAR; hyper-/multi-spectral optics (species ID); tracking of tagged fish; human diving technologies	Standard Partners; congressional mandate; state & regional; territorial agencies & councils; sport fishing; commercial fisheries; private industry (Ocean Fishing Forecasting Industry); Florida Marine Labs (Harbor Branch Oceanographic Institute, Mote Marine Laboratory); RSMAS
66	Geology & Geomorphology	Sea floor sediments Holocene (last 10,000 yrs)	What are they? How thick are they and what events do they record?	Florida deep water below 30 meters; VI; PR	Standard Package; Standard geological sampling; acoustics; develop new technologies - lasers; etc	Standard Partners
95	Human Impacts	Impacts of pollution	Anthropogenic impacts on marine mammals and their habitats from ships; blast fishing; military operations; energy refineries and energy conversion activities	Puerto Rico (super-port); Bahamas; St. Croix; Florida current; deep trenches	Sound Surveillance System (SOSUS); deployed arrays; ship surveys; systematic observations	Standard Partners
70	Marine Microorganisms	Microorganisms	Knowledge of the diversity; abundance; function; behavior; and identity of marine microorganisms; impact on ecosystems and human & habitat health	Water; sediments; organisms; wide range of depths and areas; reefs	Genomics; micro-arrays; conversion of molecular data to signals; real-time remote analysis genomics; new culture techniques	Standard Partners; NIH; Public Health Service; Pharmaceutical Industries; global climate community; reinsurance & insurance industry; Japan; Russia; France; Wood Hole Oceanographic Institution (WHOI) and ALVIN submersible; energy industries
56	Marine Organisms	All taxa biodiversity inventory	Species inventory; Identify chemical characteristics; discover and inventory new living resources (non-fishery) with commercial potential	Florida Straits; deep water habitats in Caribbean; location where there is already a lot of information such as Florida Keys or Salt River Canyon in St. Croix (long-term hydrolab mission)	Standard Package; tech diving; develop new sampling tools (new probes; sensors; samplers (miniaturized)) and new tools to keep samples alive (high pressure; low temp containers); taxonomic expertise	Standard Partners; pharmaceutical industry; biotech; medical manufacturers; equipment manufacturers; USDA; cosmetic companies; NIH; Sea Grant; NCNPR; SIO; Smithsonian; commercial operators such as charter boats, fishermen, hunters; taxonomists; many universities

Caribbean Workshop Results:						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
60	Marine Organisms	Learn status and habitats of spawning aggregations of fish	Document distribution; taxonomy; abundance; condition; and life history; mechanisms underlying fish aggregations including pelagic and benthic areas	VI; Nevassa Islands; Columbian Banks (joint treaty); VI; Puerto Rico; Bahamas; Florida Straits; Mexico; Belize; closed areas and Marine Protected Areas	Standard Package; optical technologies; visual observations; technologies that work at night; rebreathers/mixed gas; radio tagging	Standard Partners
77	Marine Organisms	Distribution of marine geographic endemics	Document taxonomy; distribution; and life history	Start at geographically distinct areas such as Florida Keys and compare to US VI	Sampling techniques; molecular genetic techniques	Standard Partners
79	Marine Organisms	Deep diving and long range marine mammals	Observe visual behavior; environment; and habitat through use of all senses	Wherever they go!; Several Caribbean wintering ground basins; nursery areas; feeding grounds	Design new technologies - non-invasive and otherwise that follow these mammals	Standard Partners
98	Marine Organisms	Connection of separated populations (esp. fish)	How Habitats impact each other	Throughout Caribbean		Standard Partners
102	Marine Organisms	Linkage between marine mammals & food source/distribution (includes vertical migrates)			Migrating instruments	Standard Partners
88	Ocean Resources - Bioprospecting	Application of new micro/macro organisms on drug discoveries & other industrial products	Biotechnology	Deep reefs; vent; seeps	Standard Package	Standard Partners

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Caribbean Region Exploration Targets of Interest

1. Anegada Passage
2. Bahamas
3. Barbados
4. Belize
5. Cayman Trench
6. Cayman Trough
7. Columbian Banks (not on chart)
8. Dry Tortugas & Tortugas Bank
9. Exumas Island Chain
10. Florida Straits
11. Islamorada Hump
12. Lang Bank
13. Mona Passage
14. Montserrat
15. Navassa Island
16. Puerto Rico – shelf bank
17. Puerto Rico Trench
18. Riley's Hump
19. Salt River Canyon
20. St. Croix
21. Tongue of the Ocean - locally known as TOTO
22. Trinidad
23. US Virgin Islands – shelf bank
24. Windward Island
25. Yucatan

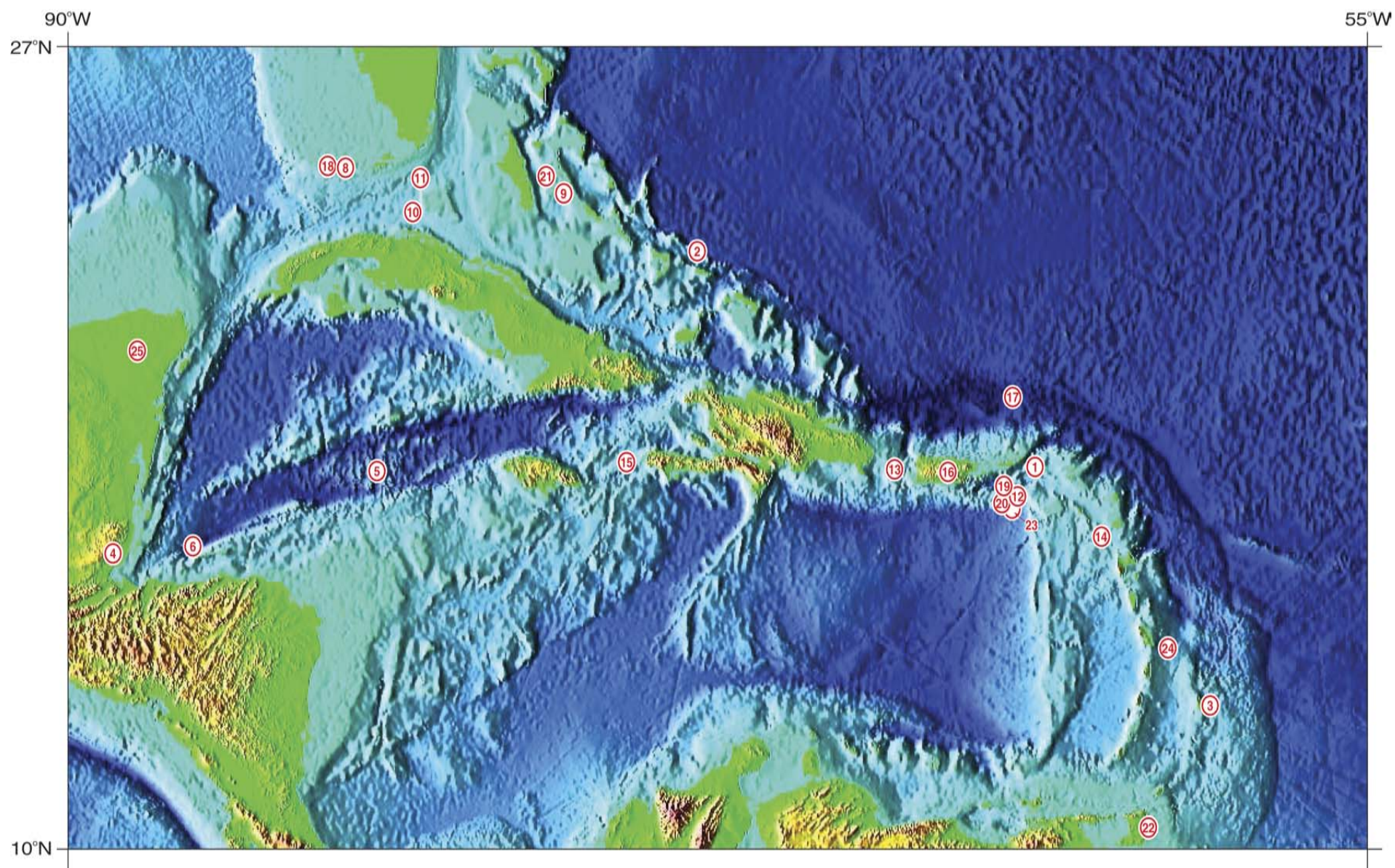


Figure 3-1. Caribbean Region Exploration Targets of Interest

3.4.2 Gulf of Mexico Region

Participants of the Gulf of Mexico workshop addressed a variety of exploration needs. There was particular interest in topics related to gas hydrates and associated chemosynthetic communities. Discussions extended beyond the traditional interest in hydrates as an energy resource and included issues related to hydrate bed stability and relationships to marine habitats. The participants also placed an emphasis on the interactions between artificial structures (such as oil rigs) and the physical environment, ocean ecosystems, and the welfare of corals and fish.

Significant discussion surrounded the availability of high-resolution bathymetric data in the Gulf of Mexico. It was noted that a significant amount of high-resolution bathymetric data and sub-bottom profiles are held by industry in proprietary databases, but this information is difficult or expensive to access due to its commercial value. There was general agreement that the OE program needed to seek innovative ways of collaborating with industry in the region to facilitate access to these data for exploration purposes.

The group initiated an interesting discussion on the Cayman Trough, an isolated ridge system located south of Puerto Rico. It is small in size when compared to other ridge systems and has been the subject of infrequent observations, making it an ideal target for exploration. Additionally, the ridge was at one time located in the Pacific during its geological history, creating interesting genetic connectivity issues that warrant further investigation. This location was identified during the Caribbean workshop and is represented in Figure 3-1.

Results for the Gulf of Mexico regional workshop are provided in Table 3-4. Exploration targets of interest nominated by workshop participants are illustrated in Figure 3-2.

Table 3-4. Gulf of Mexico Region Workshop Results

Gulf of Mexico Workshop	
Standard Package⁶: Class I/II Vessel with acoustic mapping capability (single and multibeam); dive capability (ROV/AUV/ submersible) with imagery/video; sampling equipment and high speed communications; precise positioning system	Standard Partners⁶: USGS; NASA; NOAA; Department of Energy (DOE); Coast Guard; Navy; NSF; NURP; Universities

Gulf of Mexico Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
15	Archeology	Archeological sites of historical significance	Location and dynamics of archeological sites of historical significance and cultural sites; wrecks; submerged structures; inventory and characterize what's there; record of sea level change	Candidate sites resulting from prior surveys; edge of Shelf; Bright Banks	Standard Package; Acoustic mapping; single/multibeam; sub/ROVs; Automated Wrecks and Obstructions Information System (AWOIS); video; samples; sub-bottom profiler; SCUBA; sidescan; magnetometers	Standard Partners
41	Artificial Habitats	Offshore man-made structures	Zoogeography of man-made offshore structures - oil and gas structures with time-based observations (depth is a very important component; systematic approach); oil and gas structures; Sargassum mat time-based observations at rigs (modeling; observe before and after mats pass rigs); taxonomy; diversity; distribution	Shelf and deep water; intertidal and subtidal structures	Standard package; Largely diving and ROV's; GIS commercial equipment to collect species from rigs; need industrial strength samplers; low tech recruitment plates; SCUBA; imaging; standard sampling techniques; modeling	Recreational fishing communities; big non-profits such as The Nature Conservancy (TNC); World Wildlife Fund (WWF); Ocean Conservancy; media; British Broadcasting Company (BBC); Discovery Channel; academic institutions; industry; National Geographic; standard; high potential for industrial partners

Gulf of Mexico Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
25	Benthic Environment	Biology in deep benthos	Exploring the deep benthos for biological communities; genomic mapping - non-traditional; cataloguing for biotechnology; inventory and characterize live bottom communities; deep Gulf of Mexico is most heavily studied soft bottom in world; sampling; trawls; subs; genetics; Gulf is a marginal basin - distinct zoogeographic province; mapping identifies hard surfaces - can't trawl or box core; imagery; ROV's; subs; geology important; non-chemosynthetic hard bottom poorly studied; looking for topographic highs; lithohierms; lophilia mounds; sink holes - topographic lows - have lots of fish and corals associated with them	Deep Gulf - start at around 200m	Standard Package; Box cores; trawls; subs; standard sampling; trapping; molecular tech; genetic; mapping; development of new technologies that are cost-effective; photographic surveys; ROV's (limited with currents); subs; 3-D/4-D seismic; need better sampling technologies and photographic video gear; correlating arrays; photographic monitoring; in-situ or repeat visits; chemical monitoring; census of organisms with surveys; vertical hydrophone arrays already in Gulf - can hook up with Gulf of Mexico Research Consortium	MMS; NSF; standard funding structure; Florida Marine Research Institute (FMRI); Sea Grant; Mexico; Cuba; Census of Marine Life (CoML); NIH
3	Boundary Fluxes - Air/Sea	Air/sea interactions	Understanding impact of significant weather (hurricanes; tropical cyclogenesis) on deep ocean; characterize ocean under severe weather and ocean bottom in real-time	Tropical storm tracks in Gulf	Video; acoustic mapping; hydrophones; chem./bio sensors; AUV range capability; AUV stationed underwater - "wake up"; time lapse imagery; video; sector scan sonar; hydrophones; ADCP; chemical sensors; acoustic biomass; phosphorescence sensors; genomic probe; optical spectrometer; nutrient sensors; data link; offshore meteorology; satellite data; data buoys; ocean observing systems	NWS (Hurricane Research Division); USN; NMS; NMFS; energy companies; insurance industry; vertical array (ADCP; CTD)
27	Corals - Deep Water	Distribution and status of deep water corals	Diversity; health; size/class distribution; taxonomy	Lophilia Banks - deep coral banks in outer continental shelf- Biosca Knoll; Southern Gulf of Mexico - Sigsbee Knoll and Challenger Knoll	Standard Package; Subs; Alvin or deep ROV	Standard Partners
40	Corals - Shallow Water	Turbid water coral communities	Presence and distribution; morphology	Northern Gulf region; MS River region	Food chain analysis; light meters and other monitoring equipment; water chemistry	Standard Partners

Gulf of Mexico Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
5	Currents & Water Masses	Loop currents and circulation	Interaction between loop currents; related circulation features & fisheries; and hydrate stability; impact on ecosystems and habitats; relationship between ocean properties and hydrates/beds; harmful algal bloom (HAB) formation	Yucatan Channel; shelf break along northern & eastern Gulf; loop current and depth <3km; commercial lease tracts	Standard Package; Hyperspectral sensors; ROVs/AUVs (mobility); HDTV; CTDs & hydrophones; vertical array sensors; data link; remote sensing or utilizing vessel (standard package) or fixed sensors & arrays or data mining; fixed & vessel-based ADCPs; tomography; "tailored" AUV; cameras; and sampling tools; sensors for ID nutrients; drifters; profilant floats	Standard Partners; NWS; energy industries
6	Currents & Water Masses	Gulf currents on offshore structures	Understanding of Gulf currents on offshore structures; impact on engineering and design; partnership with platforms	Northern Gulf; energy exploration areas	Instrumented platform; deployed and fixed current meters; drifters; profilant floats	Standard Partners
22	Ecosystem - Abrupt Topography	Cayman Trough	Mapping; plume prospecting; inventory and characterize	Cayman Trough just outside Gulf	CTDs; multibeam	Standard Partners
29	Ecosystem - Abrupt Topography	Lithoherms	Map; identify and characterize; geology	Between Bahamas and Florida	Standard Package; ROV; towed vehicles; AUV's; subs; geophysical technology	Standard Partners
30	Ecosystem - Abrupt Topography	Topographic areas with biological communities	Time observation of topographic areas; revisiting topographic features that have significant biological communities; change in bathymetry; time lapse data	Florida Gulf and Keys; Pinnacles off MS/Alabama; Northwest Gulf; Mexico	Time lapse video to observe activity	Standard Partners
34	Ecosystem - Abrupt Topography	Canyon systems	River-like structures at bottom; microbial communities; geochemical; origin; effects	Orca Basins; smaller brine pools elsewhere; Gulf; MS Canyon	Standard Package; Innovative microbial techniques; sampling techniques; chemical sensors; point sampling with ROV's and subs	Standard Partners
14	Ecosystem - Canyons	Characterize canyon processes	Sediment fluxes; turbidity flow; erosion; chemistry; upwelling	Mississippi Canyon; Desoto Canyon; Green Canyon	Standard Package; ROVs/AUVs/subs; video; sampling	Standard Partners

Gulf of Mexico Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
1	Ecosystem - Extreme Environments - Vents, Seeps, & Volcanoes	Hydrates and cold seeps/vents; sediment flows and biota	Understanding the relationship between hydrates and cold seeps/vents and between sediment flows and biota (including microbes) and brine pools; discover new species and processes; understand relationships	Hydrate stability zone; 300m-<~3km; northern Gulf; Campeche Banks and Bay; commercial tracts	Standard Package; 3km capable ROV; synthetic aperture sonar; laser line scanner; pressurized hydrate cores; optical spectrometers; mass spectrometers; HDTV; heat flow sensors; resistivity sensors; reusable biosensors; vertical arrays; resistivity sensors; sea-floor probes; geophones; time lapse imaging; AUV "garage"; data recovery technologies; Vessel (standard package) + high resolution seismic; Fixed sensors; Existing data mining - data bases; Remote sensing -surface expression; AUV; sub; sampling; video; moored application	Standard Partners; Naval Oceanographic Office; Naval Research Laboratory; energy companies
21	Ecosystem - Extreme Environments - Vents, Seeps, & Volcanoes	Chemosynthetic communities	(Subsurface - down several km): oil seeps and vent communities; inventory and characterize; isolated ridge system; new biota; larger geographic context; subsurface 3-D seismic surveys; biogeography (sample); locate plumes	Cayman Trough - major area to explore - lots of unexplored oil seeps; Southern Gulf; Barbados; Trinidad; West Africa - have some taxonomic affinities to those in Gulf of Mexico	Satellite images; oil data; sampling technologies; coring; access industry datasets; chemical sniffers; spectrometers; isotopic work; microbiology; molecular tools; sampling technologies; plume prospecting - do multibeam and then use sensors to look for plumes; standard package; geophysical tools; microbiologists; ecologists; molecular science; towed vehicles; subs; AUV's; look at new technologies	NOAA – Pacific Marine Environmental Laboratory (PMEL); NSF - Ridge Project; National Geographic; Alfred P. Sloan Foundation; International interest; NGO's; USGS; Universities; Mexico; EEZ states; WHOI; HBOI; NSF; MMS; DOE; NASA; ONR; Industry pharmacology; oil and gas; biotech; Mexico
43	Ecosystem - Extreme Environments - Vents, Seeps, & Volcanoes	Montserrat	Hydrothermal activity	Montserrat	Standard Package	Standard Partners
46	Ecosystem - Extreme Environments - Vents, Seeps, & Volcanoes	Neuston	Identify and characterize	Sites of persistency of oil slicks; Bush Hill - Northern Gulf	Satellite; sampling	Standard Partners

Gulf of Mexico Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
16	Ecosystem - Shorelines to Ledges	Mississippi River outflow on habitats	Understand the impacts of Mississippi River outflow on habitats; ecosystems (and secondary fresh water input); Determine river influence on Gulf systems; bio/geo/chem; frontal zones	Flower Garden Banks to FL Keys	Standard Package; Physical sampling; hyperspectral; video/HDTV; towed geo/chem/bio sensors; mass spectrometers; geo/chem/bio sensors; nutrient sensors; sensor arrays; fixed sensors; AUVs; remote sensing; ROVs; drifters; vessel	Standard Partners; NMFS; NASA; USN; NOS; Commercial fishing; sport fishing; EPA; states; NMS; U.S. Army Corps of Engineers (USACE)
35	Ecosystem - Shorelines to Ledges	Shoreline erosion	Subsidence in LA; Gulf of Mexico; erosion rates; habitat loss; sedimentation; storm surge impacts; salt water intrusion; habitat loss; impact; invasive species; impacts on infrastructure	Gulf of Mexico; TX; Alabama; coastal LA	Remote sensing; aerial photo; satellite imagery; maps	Standard Partners
13	Episodic Events	Loop and related currents to HAB formation	Understanding of relationship of loop and related currents to HAB formation and other species that are not normally seen; discover mechanisms of transport that leads to formation and distribution	West FL shelf; Yucatan Straits (source); E. Texas; northern Gulf	Remote sensing; towed arrays; ROV/AUVs; sampling; drifters (SVP); HDTV	Standard Partners
36	Episodic Events	Hypoxia phenomenon	Origin; effects	Gulf of Mexico dead zone; look at all river mouths	Collect standard oceanographic parameters	Standard Partners
9	Geology & Geomorphology	Bottom boundary dynamics	Understanding of distribution and process details of fluid and gas expulsions; carbonate formations; and seismic activity; knowledge of bottom boundary dynamics	Slope waters <3km; E. Texas to W FL slope; Continental slope; deep water; shelf; Mexico; Cuba; Florida Keys; Florida Gulf	Standard Package; Seismometers; ROVs/subs; video; sampling; map 3-D seismic data; high resolution data	Standard Partners
11	Geology & Geomorphology	Knowledge of sub-bottom characteristics	Morphology; composition; dynamics	Slope waters <3km	Standard Package; Acoustic sounders (high resolution; seismic); vertical arrays; AUVs	Standard Partners
24	Geology & Geomorphology	Rivers of warm; dense brine	Heat flow measurements; mapping; origin; effects	Sigsbee Escarpment; Orca Basin	Observations; mapping technologies; CTD; acoustics	Standard Partners
39	Geology & Geomorphology	Slope stability studies	Debris floats; gas; slopes; faults; gas hydrates; mud flows; inventory and characterization; date features	Continental slope; Mobile West; Florida escarpment; Sigsbee Escarpment	Standard Package; Geotechnical; sidescan sonar; dating techniques; sampling; core samples; high resolution geophysics; multibeam; sub-bottom systems	Standard Partners

Gulf of Mexico Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
45	Geology & Geomorphology	Mega-furrows	Origin; physical characterization over time; size; shape; currents	Found between 5-7;000 feet - base of the Sigsbee Escarpment	High resolution bathymetry; geotechnical technologies	Standard Partners
19	High Resolution Bathymetry	Mapping of the Gulf	Bathymetry	Slopes; shelf regions; western Gulf off Texas coast - East Breaks area; Eastern Gulf; all of Western Florida; 4 reserves closed to fishing - 2 in Tortugas and 2 in West Florida; Northwest Gulf; partner with Mexico to map Yucatan	Standard Package; multibeam; subs for ground truthing; utilize backscatter data; standard package; NOAA database; map; select sites; dives - selectively target between topographic features; subs; AUV's; ROV's; intellectual mapping; time series data	Oil and gas industry; MMS; NMFS; seismic companies; Harte Marine Institute; other existing efforts; USGS; Naval Oceanographic Office; Sea map, Inc.; EPA Gulf of Mexico Program (GOMP); academia; NGO's
20	High Resolution Bathymetry	Mapping between known topographic features	Mapping; inventory and characterization	All over shelf	Mapping technologies; sampling; ROV's; subs; sidescan; towed systems	Standard Partners
10	Human Impacts	Potential threat site location	Location of site of potential threat to the environment and processes near the sites; wrecks; marine debris; dump sites; abandoned platforms	Suspected debris sites; dump zones; wrecks	Standard Package; Sampling (bio/chem/physical); coring; video; acoustic mapper; radiological sensor; networked AUVs; AWOIS; time lapse imagery; video; sector scan sonar; hydrophones; ADCP; chemical sensors; acoustic biomass; phosphorescence sensors; genomic probe; optical spectrometer; nutrient sensors; data link; single/multibeam; sub/ROVs; AWOIS; samples; data mining (data bases); fixed sensors and arrays	EPA; NMS; State Governments; NOS HAZMAT Response Group; media
32	Human Impacts	Anthropogenic noise	Monitoring natural (biological and geological) and anthropogenic noise; effects of human induced noises on biota; natural noise	MS Delta where whales are located; human built platforms; protected regions; essential habitats	Acoustic technologies; new technologies	Standard Partners

Gulf of Mexico Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
4	Marine Conservation	Marine Protected Areas	Characterize "deep" Marine Protected Areas (including deep reefs); identify candidate Marine Protected Areas; location & dynamics of archeological sites of historical significance through the use of: vessel (standard package); data mining; manned observatory; fixed sensors and arrays; ID biota that needs protection; habitat characterization	Existing Marine Protected Areas (3 W. FL shelf); Flower Garden Banks; Green Canyon; Mississippi Canyon; Desoto Canyon; PSBL Yucatan Channel	Sub/ROV; deep diving capabilities; manned observatory (human habitat); fixed sensors; AUV; good video; acoustic mapping (single/multibeam); HDTV; synthetic aperture sonar; laser line scanner; data mining technologies; deep water capability; time lapse imagery; data link	Energy companies; NURC; NMFS; Universities; USN; NIH; state governments; commercial fisheries; sport fishing
12	Marine Organisms	Distribution and migration patterns of mega fauna	Understanding distribution and migration patterns of marine mammals; charismatic mega fauna (whales; manta rays; sea turtles; dolphins; whale sharks; etc); response to anthropogenic impacts (noise; other pollution); location; reproduction; general life history questions; genetics	Migration routes; commercial lease tracts (1km contour and loop current events); Gulf shelf; specific topographic features associated with them; man-made platforms	Satellites; various tagging equipment and tech (pop-up; etc); smaller vessels; genetics; endocrinology; biochemistry; Standard package - largely diving and ROV's; GIS commercial equipment to collect species from rigs; need industrial strength samplers; photo equip; ROV's; subs; in-situ cameras; motion sensor cameras; time-lapse cameras; acoustic tags; fixed hydrophones; sensor arrays; tagging; imaging; acoustic; hydro acoustic	Recreational fishing communities; big non-profits such as TNC; WWF; Ocean Conservancy; media; BBC; Discovery Channel; academic institutions; industry
26	Marine Organisms	Genetic connectivity of Gulf ecosystems	Biodiversity; genomic mapping	Upstream and downstream of productive fishery areas – Marine Protected Area's; Keys; Banks; major eddy systems	Genetic technology; plankton tows; traditional sampling techniques; ROV's and subs; deep water collection	Standard Partners
42	Marine Organisms	Exotic invasive species	Where do they come from?; how did they get here?; where are they successful or not successful?; impact; taxonomy; genetics	Everywhere from coast to far offshore regions	Standard sampling; genetics; taxonomy; modeling	Standard Partners
44	Marine Organisms	Cross Gulf migratory birds	Migratory birds - songbirds; contribute to database	Western Gulf mainly; Cuba to Florida	Visual observations; radar	Standard Partners

Gulf of Mexico Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
2	Ocean Resources - Energy & Minerals	Gas hydrates	Understanding and determination of location and volume of hydrate resources; classification; chemistry	300m-3km (maybe more) depths; emphasize below 1000m (E. Texas to W. Florida); EEZ; outcroppings; arctic	Acoustic mapping; ROVs; sampling systems; video; sub; AUVs; sensors for gas analysis	Standard Partners
17	Ocean Resources - Energy & Minerals	Location of new mineral resource deposits	Shell; sand	EEZ	Core samples; ROVs/AUVs	Standard Partners
18	Ocean Resources - Energy & Minerals	Ocean renewable resources	Ability to generate energy from ocean renewable resources (currents; vents); detailed baseline knowledge of candidate currents/locations	Candidate bathymetry near loop and related currents; vent locations	Instrumented platform; deployed and fixed current meters; drifters; profilant floats	Standard Partners
38	Pelagic Environment	Mid-water exploration	Characterization of organisms	Gulf; off mouth of MS river - resident population of sperm whales over 1000m line so there must be a resident population of giant squid; Straits of Yucatan and Straits of Florida - Gulf connections	Mochness; imagery; sensing; new technologies	Standard Partners

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Gulf of Mexico Region Exploration Targets of Interest

1. Bright Banks
2. Bush Hill
3. Campeche Banks
4. Challenger Knoll (not on chart)
5. Coastal Louisiana
6. Cuba
7. DeSoto Canyon
8. East Breaks area
9. Florida Escarpment
10. Florida Keys
11. Flower Garden Banks
12. Green Canyon
13. Lophelia Banks (not on chart)
14. Mexico – areas off Mexico
15. Mississippi Canyon
16. Mississippi Delta
17. Orca Basin
18. Portales Terrace (not on chart)
19. Pulley Ridge
20. Shelf break along northern & eastern Gulf
21. Sigsbee Escarpment
22. Sigsbee Knoll (not on chart)
23. Tortugas Gyre/Portales Gyre
24. Viosca Knoll
25. Yucatan Channel
26. Yucatan Straits

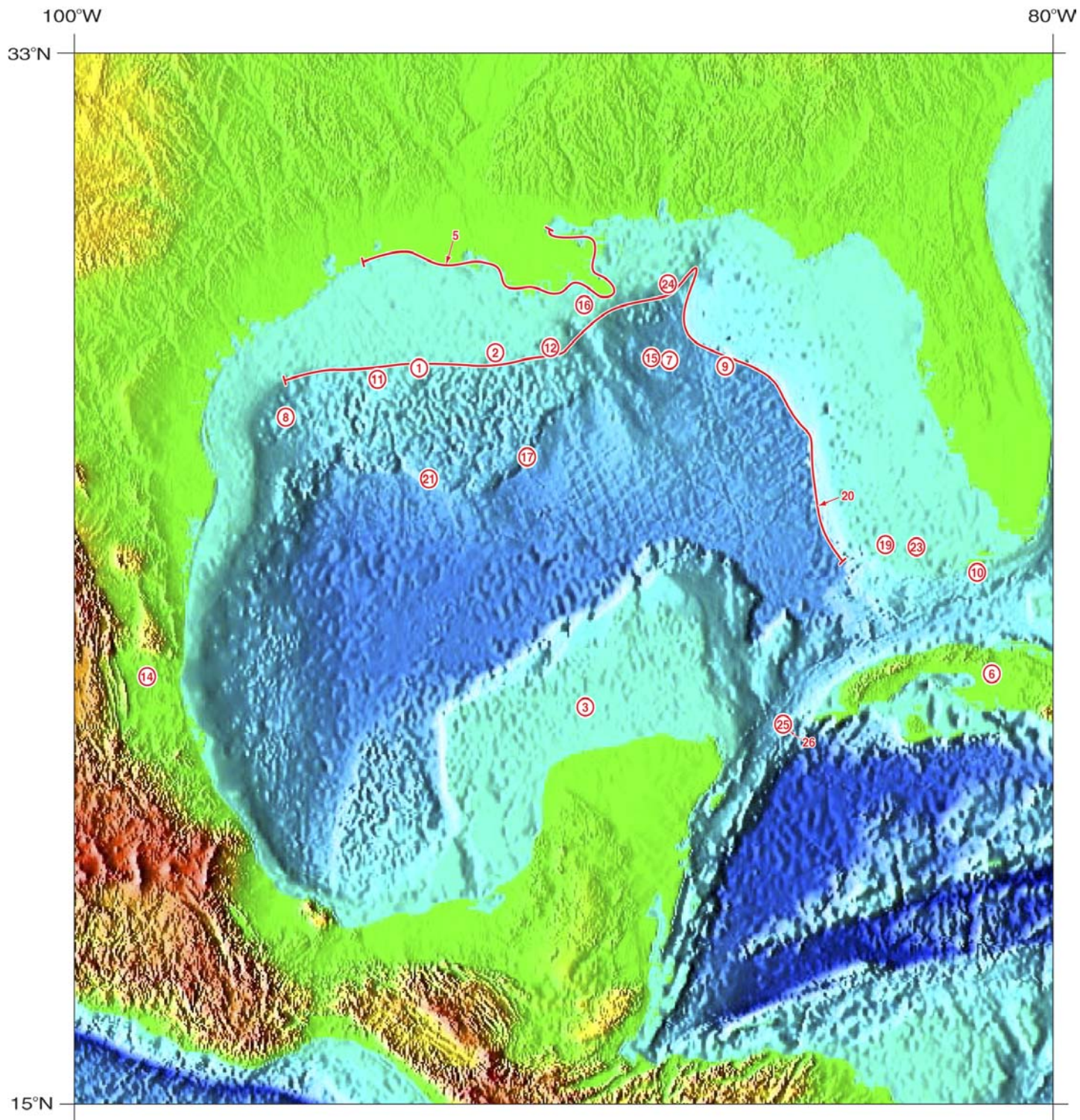


Figure 3-2. Gulf of Mexico Region Exploration Targets of Interest

3.4.3 Hawaii Region

While the attention of the Hawaii region workshop participants was naturally on the waters surrounding Hawaiian Islands, other areas of interest in the Pacific were identified including Micronesia and Pan-Pacific arcs and trenches. Exploration of the characteristics of microbes in extreme environments and of marine organisms in the water column were noteworthy interest areas in this workshop. A specific interest was the desire to explore trench systems across the Pacific to discover and identify new species. In the local region, participants were interested in the natural history of the islands and expressed a desire for emphasis on marine archeology to preserve the local maritime heritage.

The lack of high-resolution bathymetric maps in the region provided a common talking point in discussing the formulation and identification of exploration needs. The participants also showed interest in reestablishing the Hawaii Undersea Geo-Observatory (HUGO), a submarine observatory located near the summit of Loihi Seamount and connected to the shore via fiber optic cable. HUGO has been inoperative since April 1998. It was identified as a potentially beneficial technological asset for addressing several of the exploration needs developed by the participants.

The results for the Hawaii region workshop are provided in Table 3-5. Exploration targets of interest nominated by participants for the immediate area surrounding the Hawaiian Islands and for broader areas of the Pacific are illustrated in Figures 3-3 through 3-5.

Table 3-5. Hawaii Region Workshop Results

Hawaii Workshop	
Standard Package: Class I/II Vessel with acoustic mapping; Dive capability (ROV/AUV/ Submersible) with imagery/video and sampling equipment; Precise positioning system	Standard Partners: University of Hawaii; State of Hawaii; NMFS; NOS; NMS; USCG; Bishop Museum; Hawaii Department of Land and Natural Resources (DLNR); Hawaii Division of Aquatic Resources (DAR); Sea Grant; Hawaii Undersea Research Laboratory (HURL); DOE; Fish and Wildlife Service; Navy Historical Center; National Park Service; USGS; ONR; NSF

Hawaii Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
113	Archeology	Understanding population from geological records	Study fossil records; population over geologic time	Kaneohe Bay	Standard Package	Standard Partners
114	Archeology	Extinct species (fossil reefs)	Study carbonate samples; date; taxonomy	Deeper the better; NW HI; Emperor Seamount chain; Kure and other seamounts up the chain	Standard Package	Standard Partners
117	Archeology	Submerged archeological sites	Near-shore low impact visual survey - targeted historical research; archives; non-invasive documentation; Mid-water remote sensing - documentation to narrow down to select survey areas; groundtruth targets; Deep water - survey targeted areas then groundtruth	Kure Island - one of most significant wrecks in Hawaii - Naval Historical Center probably interested in this site; protected zone off Pearl Harbor - several subs there - historic landing sites; Nihoa Island and Necker Island; wider Pacific; US Insular Pacific; Hawaiian Islands - Oahu; big island Hawaii; Kure; Pearl Harbor; Midway; Lanai (shipwreck beach); Midway atoll environs (aircraft); Alenuinui channel between Hawaii and Maui; dumping grounds SW of Barber's Point Oahu; Historic defensive zone outside Pearl Harbor entrance; Areas near shore to Lahaina; Honolulu Harbor; Hilo Bay; Midway atool environs (aircraft); Alenuinui channel between Hawaii and Maui; dumping grounds SW of Barber's Point Oahu; Historic defensive zone outside Pearl Harbor entrance; Areas near shore to Lahaina; Honolulu Harbor; Hilo Bay; Waialua Bay Waialua Bay	Small vessels; side scan sonar; magnetometer; technical and advanced diving; aerial survey or remote sensing; technology dependent on location and type of wreck - later excavation; conservation; and display - need conservation facilities; microbial technologies; microchip technology	Standard plus the following: National Geographic, Discovery Channel, DOI, State Historic Preservation Division, Hawaii Historical Foundation, Hawaii Community Foundation, Bishop Museum, Coastal Maritime Archaeology Resources (CMAR), other small NGO's, Smithsonian

Hawaii Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
140	Archeology	Natural history of Hawaiian Islands	Geological controls on marine biota	Hawaiian archipelago; surrounding pelagic waters; NW Hawaii - French Frigate Shoals; SE Hawaii - Big Island	Standard Package; airborne hyperspectral surveys; ground truthing; multi-platforms; mobile observatories	Standard Partners; Japan Marine Science and Technology Center (JAMSTEC)
132	Benthic Environment	Infaunal organisms	Taxonomy; Sediment ecology	Compare Northwestern Hawaii to others down chain; different depths; soft bottom	Standard Package; Sampling; multibeam; coring	Standard Partners
135	Benthic Environment	Characterization of bottom habitats	Broad scale characterization; match fish species to bottom characteristics; collect ground truth with deep tow side scan sonar; seafloor sediments characteristics; bottom currents	Samoa; Mariana's Islands	Standard Package; ROVs fly through canyon fishing; swath; deep tow; remote sensing of shallow areas; acoustic surveys	Navy; WHOI; University of Hawaii
143	Boundary Fluxes - Air/Sea	Climate change	Feedback of ocean change on biota -through observation approach time series with El Niño events: determine impacts on equatorial Pacific biological pump; long term; carbon fluxes in thermocline	Equatorial Pacific S. America; Galapagos; Toca Tao Arrays	Genetic sampling; satellite (remote sensing); mass spectrometer; sediment traps/cameras; fluorescent signal of phytoplankton species	Standard partners
110	Currents & Water Masses	Current patterns and gyres and how they are changing	Food production; marine debris deposits; how do they change and how are they affected? (larval transport)	HI Archipelago - large system focus	Satellites; Time observations; Floating instruments; Physical oceanography; Molecular techniques to look at long-term dispersal patterns	Standard Partners
111	Currents & Water Masses	Internal waves	Physical oceanography; internal tides	Sea mounts - 2002 proposal sites	ADCP; long-term moorings	Standard Partners
119	Ecosystem	Identifying ecologically critical habitats	Temporal / spatial observations; mapping; then direct observations; diversity; location; substrate type; visual information; reflected imagery; community structure; locating critical habitats with Critter Cam (animal borne camera) system; use existing and historical information	Intermediate depth regions; wide range of depths - mostly moderate depths to deeper depths; NW HI Islands - 2002 sites as specified in 2002 proposals; US Pacific Insular Islands; Guam; Samoa; CNMI	Standard Package plus; ADCP; current meters; multibeam; Same as tagging technologies; archival capability	Standard partners plus outreach partners, fishermen, National Geographic, Discovery Channel; recreational divers

Hawaii Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
109	Ecosystem - Banks & Basins	Banks	Survey; map; ground truthing; sampling; direct observations; ID and characterize organisms as well as features	Penguin Banks; NW HI Banks	Standard Package; genomic technologies; coring; molecular techniques; video live feeds for outreach; HUGO at Loihi volcano; dating technologies	Standard Partners, HUGO, telephone companies, outreach partners, National Geographic, Discovery Channel, drug companies, MMS
108	Ecosystem - Basins & Banks	Solution Basins	Survey; map; ground truthing; sampling; direct observations; ID and characterize organisms as well as features	Off Maui	Standard Package; genomic technologies; coring; molecular techniques; video live feeds for outreach; HUGO at Loihi volcano; dating technologies	Standard partners, HUGO, telephone companies, outreach partners, National Geographic, Discovery Channel, drug companies, MMS
106	Ecosystem - Canyons	Submarine canyons	Survey; map; ground truthing; sampling; direct observations; ID and characterize organisms as well as features; carbon cycling; areas of high productivity; ID and characterize communities; maps	Kaneohe Canyons; Haleiwa Canyon; Waimea Canyon	Standard Package; genomic technologies; coring; molecular techniques; video live feeds for outreach; HUGO at Loihi volcano; dating technologies; bait deployment	Standard Partners, HUGO, telephone companies, outreach partners, National Geographic, Discovery Channel, drug companies, MMS
107	Ecosystem - Seamounts / Ridges	Seamounts	Locating unknown seamounts; identify and characterize communities; identify new species; altimetry mapping comparisons; geoid products; deep seamount biomass understanding; survey; map; ground truthing; sampling; direct observations with moored stations & deep dives; verifying location; sampling; mapping; deep scattering layer over hydro plumes	Northwestern Hawaii to start comparing altimetry w/ navigation charts; West Mounts; Necker Ridge; Hawaiian Islands; Musician Seamounts and then look outside to examine dispersal; evolution; many seamounts have no names; Emperor Seamounts	Standard Package; genomic technologies; coring; molecular techniques; video live feeds for outreach; HUGO at Loihi volcano; dating technologies; better altimetry sensors and data processing; improved spatial coverage; altimetry maps; swath bathymetry; gravity survey; fishing boat watching	Standard Partners, HUGO, telephone companies, outreach partners, National Geographic, Discovery Channel, drug companies, MMS; NESDIS; NASA; Navy
144	Ecosystem - Trenches	Trenches	Tonga Trench; deep dive mapping; gas hydrates	Mariana's Trench; Tonga Trench	Extreme deep diving for ROVs; sampling tech	JAMSTEC; NSF – Margins Program

Hawaii Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
138	Ecosystems - Arc	Gaps in exploration in past of arcs	Standard plume techniques at Tonga Kermadec; less than 2% been explored; location of chemical fluxes and plumes; biota; volumetric; geologic signatures; tracing ocean circulation; sensing water column	Euphotic zone in Tonga Kermadec Arc	Standard Package: Airborne remote sensing surveys; expendable bathythermographs (XBTs); high precision; standard package; tow-yo	PMEL; Geologicaland Nuclear Sciences Limited (GNS); JAMSTEC; NSF - Ridge Program; American Samoa; NMFS; NMS
120	Extreme Environments - Vents, Seeps & Volcanoes	Formation of biofilm/microbial mat in extreme environments	Diversity; members of consortia; genome mapping; discovery of new antibiotics; chemistry of the environment	Loihi hydrothermal vent; New Zealand; Mariana's Trench; any extreme environment	Coring technology; Genomic; protein chemistry; microchip; confocal microscopy; develop portable confocal for ship use; small gc/ms; subs and other collection vehicles	Standard Partners
122	Extreme Environments - Vents, Seeps & Volcanoes	Active volcanism	General mapping; Access naval data; Airborne geochemical; Seismic; Passive acoustics; track plumes and trace elements from plumes from air; set up listening arrays; locate features using mapping technology	Am. Samoa; New Zealand; Japan; CNMI; Guam - throughout Pacific	Standard package plus remote sensing; thermal technology; magnetometers; seismology; acoustic technology; mapping technology; passive acoustic arrays; live feed for outreach	Standard partners, Navy, National Geographic, Discovery Channel, deep sea mining community, New Zealand, Japan, Island Nations, Indonesia, Australia, maritime industry, biotech, minerals
133	Extreme Environments - Vents, Seeps & Volcanoes	Understand the Pacific Ocean regarding the origin of life (vent communities, any optimal environments, etc) - A. Funnel (including Tow-Yos)	Interaction between geology; biota; circulation area to target (Tow-Yos - sampling in vertical)	Loihi - volcano; hot spot; Juan de Fuca; cold seeps; Back Arc Basins (Guam; Samoa; Lau)	Standard Package; specific sampling; HDTV; digital camera systems; sampling and incubation systems for culturing organisms	JAMSTEC, University of Washington, PMEL, NASA, GNS, Center of Marine Biology at Maryland (COMB)
142	Extreme Environments - Vents, Seeps & Volcanoes	Sample and map new hot spots; fundamental understanding	Investigate Loihi; Samoa; Louisville Ridge; sampling deep mantle plume; sample volcanic edifice edge of seafloor	Samoa; Loihi	Standard Package; ocean bottom observatories; SOSUS; Sonobuoys Ocean Bottom Seismometer; Acoustic	SOSUS; Isla - Infra Sound Lab (U.N.); HUGO; USGS; GNS

Hawaii Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
112	Geology & Geomorphology	Paleoshorelines	Sea level information such as history; finding wave notches; ledges; other geomorphological features; lava tubes and marine caves - biology	HI Archipelago (focus in NW and main islands - Midway; Oahu; Necker; Brooks; Lisianski)	Coring technology; Advanced diving; Subs and other vehicles; multibeam for mapping; Animal borne instrumentation	Standard Partners
127	High Resolution Bathymetry	Charting of seamounts and banks	Mapping with more sophisticated technology	All submerged banks; particularly those that can't be seen through aerial photography; Northwestern Hawaii at 25-100 fathoms	Standard Package with multibeam	Standard Partners
116	Human Impacts	Pollution and marine pathogens	Use pathogen count as a marker	Event driven; Kaneohe Bay; Pearl Harbor; sewage outfall	Molecular biology techniques; genomic	Standard Partners
131	Human Impacts	Safe nuclear waste disposal site				Standard Partners
141	Human Impacts	Understanding biomagnification of pollutants and toxins in the marine food web (similar to large pelagic)	Reef fishes; quantifying toxins	Kona coast; Ecuador; Peru; Alaska	Tracer technologies; genetic markers; sampling and ID tools; stable isotopes will vary; stable isotopes; fatty acid analysis; modeling	Standard Partners; EPA
115	Marine Microorganisms	Marine parasite lifecycles	Documenting parasites; life cycle; primary and secondary hosts	Compare regions to look for pollution relationships; Northwest Hawaii	Fishing; sampling technology; subs; genomic; histopathology; specimen collection	Standard Partners
129	Marine Microorganisms	Marine viruses	What are the effects on carbon and phosphorus cycling?	Oahu; Station Aloha (permanent sampling site - mooring)	Water sampling, virology, bacteriology, molecular biology techniques	Standard Partners

Hawaii Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
118	Marine Organisms	Animal distribution patterns	Opportunistic (fisheries) adults-only tagging through existing operations such as fishing industry; targeted adult tagging - mark-recapture of marine mammals; photo identification; track over time with tags and acoustic moorings; genomics (can be part of tagging and/or tracking); collect tissue and analyze; otolith elemental fingerprinting - collect specimens through HI Arch. and analyze; larval distribution patterns - collect and identify samples	HI Archipelago (Hoomalu and Mau regions - have at least one site in each region; also big island site); specific relationship between main HI and NW HI and between Johnston Atoll to S. Japan; island to island; bank to bank relationships	Standard Package; RAPT system for tracking; tags; cameras; tracking devices; genomic; develop new faster genomic technologies to be used on ships; current meters; ADCP; molecular techniques to identify larvae; aerial survey; digital ID tools; fingerprinting technology; plankton tows	Standard Partners; plus fishermen - recreational and commercial
121	Marine Organisms	New species/records inventory	Identify new species through existing expeditions recording abundance and diversity; taxonomy; going to areas and habitats that are not well documented	Northwest Hawaiian Islands (NWHI) (2002 proposal sites) - far islands such as Kure and beyond where there have been no subs thus far; get close to N Pacific transition zone; US Insular surveys; maybe look at some equatorial areas for comparison	Standard Package; Plus molecular and genomic techniques; Coring technology; Advanced diving; Subs and other vehicles; multibeam for mapping; Animal borne instrumentation	Standard Partners plus fishermen, Smithsonian, New Species Consortium, Sloan Foundation, National Geographic, Discovery Channel, Packard Foundation
128	Marine Organisms	Coelacanth, giant squid, megamouth (obscure, unknown critters)	Location; habitats; population distribution; abundance; genetics; images	Indonesia (coelacanth); HI; California (Pacific) (megamouth); New Zealand (giant squid)	Standard Package; Imaging; Subs; ROV's	Standard Partners
134	Marine Organisms	Marine biodiversity - inventory from Hawaii Islands - Deep Marine (>200m - ~6500m or beyond)	Along and around Hawaiian Ridge & link investigators to coordinate discovery	NW Hawaiian Islands to compare species; deep ocean areas	Standard Package; Observatories at depth; deep ocean sampling instruments; low light cameras; video; acoustics; AUVs; deep submersible; ROVs; benthic observatories; in-situ observatories; self cleaning camera lenses; Critter Camera technology; rugged low light cameras	Standard Partners; JAMSTEC; ONR; National Geographic; NMFS; US Fish & Wildlife Service

Hawaii Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
139	Marine Organisms	Understand habitat of large pelagic animals	Migration corridors; use of ocean; vertical movements - targeted & observational commercial/research vessels for tagging; satellite data comparisons for behavior patterns; acoustic subsurface surveys (foraging) by attaching instruments to animals - movements; fronts; eddies; interaction with benthos; linking foraging with physical environment	Central Pacific (around Hawaii); coastal Kona (Big Island); ship of opportunity; Hawaiian Ridge	Standard Package; Critter Cam technology; satellite archival tags; ARGOS; remote sensing; acoustic surveys; instrument research technologies attached to animals	Standard Partners; Fishery Management Council; Hawaii Longline Assoc; National Fish & Wildlife; National Geographic; National Institute of Water and Atmospheric Research (NIWA - New Zealand); Commonwealth Scientific and Industrial Research Organisation (CSIRO - Australia); South Pacific Regional Environment Program (SPREP)
126	Ocean Resources - Energy & Minerals	Mineral resources	Location; composition	Johnston sea mount; other sea mounts	Standard Package; multibeam	Standard Partners
123	Sound in the Ocean	Ocean acoustics		Hawaii Archipelago (Northwestern and main Hawaii mapping); Guam; Commonwealth of the Northern Mariana Islands (CNMI); American Samoa; deeper areas	Sonar - active and passive; use subs and other vehicles for in-situ measurements; archival measurements	Standard Partners

Hawaii Region Exploration Targets of Interest

1. Emperor Seamounts
2. French Frigate Shoals
3. Guam
4. Haleiwa Canyon
5. Indonesia
6. Johnston Atoll
7. Kaneohe Bay / Kaneohe Canyons
8. Kure
9. Lanai
10. Loihi
11. Marianas Islands
12. Marianas Trench
13. Marquesas
14. Midway
15. Musician Seamount Province
16. Necker Island
17. New Zealand
18. Nihoa Island
19. Oahu
20. Pearl Harbor
21. Penguin Bank
22. Samoa
23. Station Aloha [45.00' N, 158 00.00] (not on chart)
24. Toga Tao Arrays (not on chart)
25. Tonga Kermadec Arc
26. Waimea Canyon
27. West Mounts

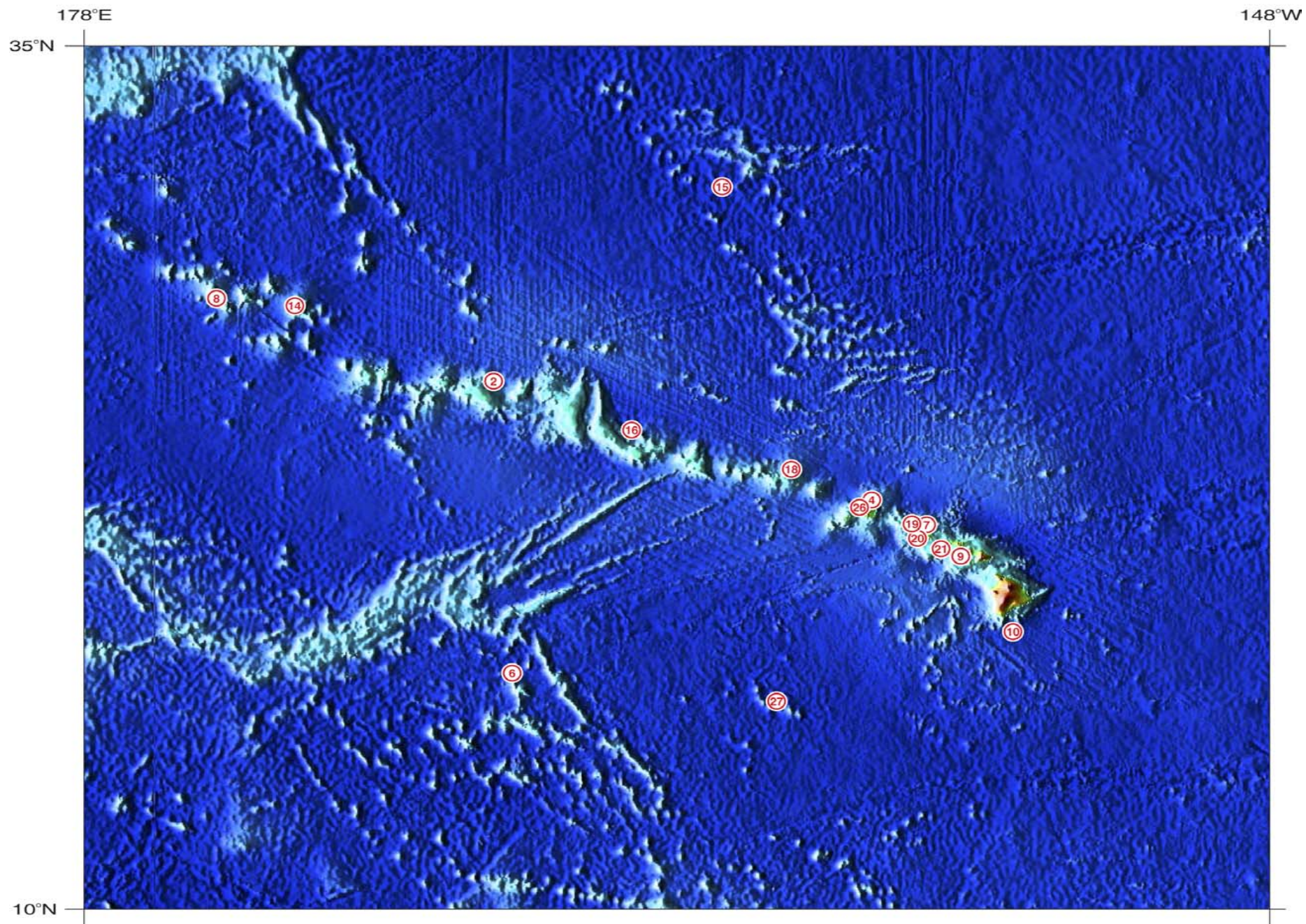


Figure 3-3. Hawaii Region Exploration Targets of Interest – Vicinity of Hawaii

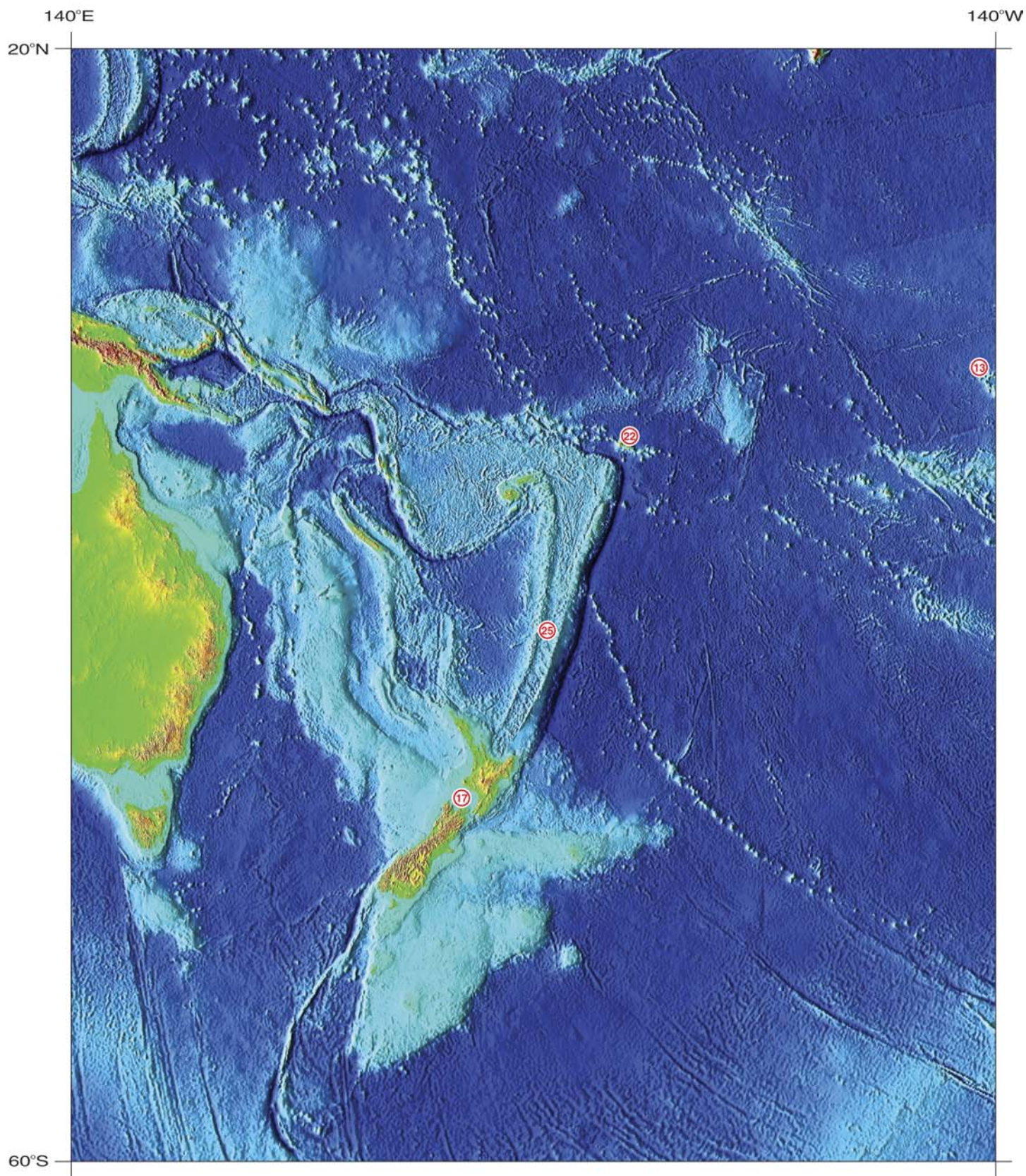


Figure 3-4. Hawaii Region Exploration Targets of Interest – South Pacific

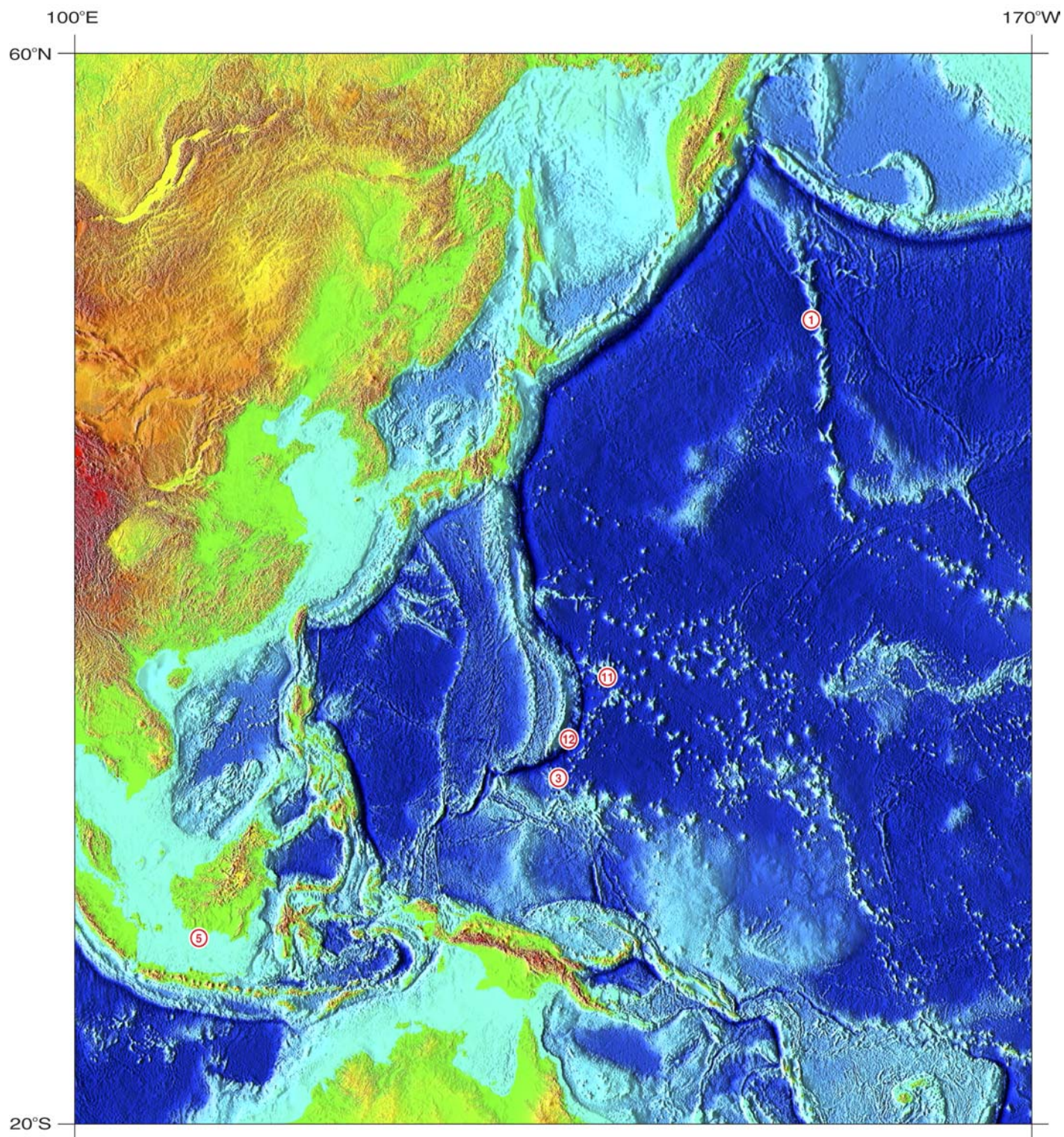


Figure 3-5. Hawaii Region Exploration Targets of Interest – Western Pacific

3.4.4 Alaska Region

The workshop discussions in the Alaska region began by focusing on ecosystems in marginal ice areas and the methods by which these ecosystems adapt in such an abruptly changing environment. Additional discussion emphasized areas of the seafloor that had been previously scoured by glaciers. One item that had unique attention in this workshop was the interest in the exploitation of traditional local knowledge—indigenous inhabitants of the region—to help establish a knowledge baseline for facilitating exploration beyond the usual application of scientific knowledge.

This workshop provided a forum for participants to emphasize the true frontier nature of the region. Much of the Alaska region is unexplored due to its size and the extreme wintertime environment. The lack of existing knowledge led the attendees to focus on the application of ocean exploration in relative large regional areas rather than specific targets. Likewise, considerable attention among the participants was devoted to ocean exploration during the winter season since so few observations are made during this time and much remains to be learned about the wintertime ocean environment.

The Alaska region workshop results are provided in Table 3-6. Exploration targets of interest nominated by participants are illustrated in Figure 3-6.

Table 3-6. Alaska Region Workshop Results

Alaska Workshop	
Standard Package: Class I/II Vessel with acoustic mapping; Dive capability (ROV/AUV/ Submersible) with imagery/video and sampling equipment; Precise positioning system; bench mounted ocean instruments; good pumped water (rapid input); gas detection system; ADCP; bioacoustics profiling system; multibeam system; sediment and rock sampling system; bongo tow	Standard Partners: NOAA (Office of Marine and Aviation Operations (OMAO); NESDIS; NOS; Coast Survey); NURP; NMFS; Air Force Civil Engineering (AFCE); NOPP; University of Alaska; Oregon State University; University-National Oceanographic Laboratory System (UNOLS) Community; Alaska Native Science Communities; MMS; USGS; Prince William Sound Science Center; North Pacific Research Board; US Fish & Wildlife Service

Alaska Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
171	Archeology	Shipwrecks including, pre WWII, WWII and Later Human Sites	Location and characterization of site; documentation of artifacts; document effects on ecosystems and food chain	Western Aleutian Islands; Kiska Island; Duke Island (SE AK); Attu Island; SE Alaska; Lynn Canal	Standard Package; archive searching; special equipment for artifacts - lab facilities for preservation & stabilization; human diving	Standard Partners; Museums; Salvage Organization; State Historic Preservation Office
175	Archeology	Archeological Information on Human Migration	Location and characterization ancient villages; Document migration routes; Document ice records	Fairweather Ground	Standard Package; archive searching; special equipment for artifacts - lab facilities for preservation & stabilization; human diving; very high resolution side scan (w/ backscatter data)	Standard Partners; Museums; Salvage Organization; State Historic Preservation Office
160	Benthic Environment	Relationship of Benthic Features and Essential Fish Habitats	Catalogue the distribution and abundance of the types of species that are in the mesopelagic zone; document the benthic habitats that support important ecosystem components including fish and rare or special species and essential fish habitats	Continental shelf; Gulf of Alaska; Bering Sea; Chukchi Sea; shelf edge and basin of Gulf of Alaska	Standard Package; bottom profiling technologies; optics; satellites; nets; tagging; underwater visual technology; pop-up satellite archival tags (PSATS)	Standard Partners; Fishing industry
170	Currents & Water Masses	Circulation survey	Document subsurface currents	Western Alaska; Nome; Bering Sea; Chukchi Sea	Standard Package; moorings; remote sensing	Standard Partners

Alaska Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
181	Currents & Water Masses	Need data and information on large-scale circulation and variability of Beaufort Gyre	Explore largest freshwater reservoir	Beaufort Sea / Arctic Ocean	Standard Package; remote sensing; autonomous platforms; ice-going vessels; moorings	Standard Partners; Canadian Government (Earth Science Sector)
159	Ecosystem	Bering Sea fish habitats	Use bathymetry to understand sediments and habitat; use hydrography for better understand of tidal data; understand temporal nature of biology	Gaps in data of Bering Sea - Bristol Bay	Standard Package; Ships of opportunity; interferometric side scan sonar (true swath bathymetry and true backscatter)	Standard Partners; commercial partners; fishing industry
344	Ecosystem	Alaska Region Ecosystems	Comparison of transects across the eastern, central, and western Aleutians	Aleutians	Standard Package	Standard Partners
147	Ecosystem - Abrupt Topography	Fjords of southeast and south central Alaska	Contrast recent glaciated landscapes to more stable and tidewater to non-estuaries; compare tidewater glacial vs. nonglacial; document substrates for habitat mapping; detect species distributions; determine some of physical and biological effects of deglaciation (they have complex oceanographic regimes and teasing out would be good)	Glacier Bay; Prince William Sound; Icy Bay; Substrates for habitat mapping; especially the deep and dynamic fjords	Standard Package; CTD; divers; ships of opportunity; HDTV; Remote Sensing Satellite (ASTER; LANDSAT 7)	Standard Partners; Cruise lines
152	Ecosystem - Abrupt Topography	Aleutian Trench	Inventory and document geology (improved mapping) and habitats esp. corals and methane seeps; document these trophic systems; identify new species	From start to very end of Aleutian Chain	Standard Package; Coring; deep vehicle capabilities; high pressure samplers; deep tow; rock dredging	Standard Partners; JAMSTEC
153	Ecosystem - Abrupt Topography	Aleutian Arc	Examine the structural arc; examine substrates and patterns of coral distribution; document hydrothermal venting and volcanism; document biodiversity; biology; and oceanography	Region between the islands and north of the Arc (abyssal plain); from southern boundaries of the platforms; north to abyssal plain of the Bering Sea	Standard Package; water column methane sniffing; AUVs for mapping broad shallow areas of continental shelf (Much better than using surface ship. MBARI has developed vibracoring system which could be adapted for this project); Coastal Detection and Ranging (CODAR)	Standard Partners; Russia

Alaska Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
154	Ecosystem - Abrupt Topography	Canyons	Document rate of the consumption of the physical plate; geochemistry; sediment transport; and volcanism; examine biology of area; and hot springs seeps; examine these very interconnected physical systems; inventory and document geology (improved mapping)	Southeast Alaska; Aleutians; Deep Canyons in Aleutian Fore Arc (POC - Phillip Rigby and Gene Yogodzinski); Bogoslov; near sub volcanoes; Bering Sea Canyon; Kodiak Seamount	Standard Package; submersible (7000 m) technology that allows you to hold station in strong current; trawls; nets; visualization techniques; physical oceanography tools	Standard Partners
168	Ecosystem - Abrupt Topography	Submarine seamounts	Document evolution of seamounts; circulation; and currents; document these ecosystems esp. in the deep water	South central Gulf of Alaska (Gulf of Alaska Seamount Province) e.g. Pratt-Welker Chain; Patton Murray Chain; South of the trench (e.g. Adak Island; Central Aleutians; Atka Island)	Standard Package; new technology (e.g. video to speed up processing); HDTV	Standard Partners; MBARI; Navy
151	Ecosystem - Extreme Environment - Sea Ice	Characterize and explore extreme environments	Characterize and explore high salinity and low temp environments	Bering Basin / Arctic Ocean	Standard Package; extreme cold technology; biochemical genetic screening; tagging; remote sensing; ice breaker ships; thermal imaging; Nation Technical Means; aircraft; acoustic monitoring	Standard Partners; Industry; Navy; US/Canadian/Russian Coast Guard; NSF; Arctic Logistics; Barrow Arctic Science Consortium (BASC); VECO Corp.
162	Ecosystem - Extreme Environment - Sea Ice	Seasonal (winter) exploration	Biological; geological; cryosphere; biological and physical oceanography	Continental Shelf spawning area; Bering Sea (Bristol Bay; northern Bering Sea e.g. along the ice edge; central Arctic Basin; whole ice edge); Cook Inlet (issue - other organizations working on it).	Standard Package; extreme cold technology; biochemical genetic screening; tagging; remote sensing; ice breaker ships; thermal imaging; Nation Technical Means; aircraft; acoustic monitoring; full blown submarines	Standard Partners; Industry; Navy; US/Canadian/Russian Coast Guard; NSF; Arctic Logistics; BASC; VECO Corp.
163	Ecosystem - Extreme Environment - Sea Ice	Sea ice	Document biology and physical processes going on; Ballena studies; Increased fetch (expanded open ocean); document change in migration patterns; role of sea ice cover in structuring the marine ecosystem; how does it vary with latitude	Nearshore reefs e.g. Camden Bay. Along Arctic barrier islands. Some of the Bering Sea Islands for coastal erosion. Beaufort Seas; Chukchi Sea; Bering Sea	Standard Package; extreme cold technology; biochemical genetic screening; tagging; remote sensing; ice breaker ships; thermal imaging; Nation Technical Means; aircraft; acoustic monitoring; vessels of opportunity; ice-going vessel; ice moorings; autonomous platforms	Standard Partners; Industry; Navy; US/Canadian/Russian Coast Guard; NSF; Arctic Logistics; BASC; VECO Corp.

Alaska Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
177	Ecosystem - Extreme Environment - Sea Ice	Wintertime trophic food web	Identify and catalogue the trophic webs that support birds and mammals in the wintertime; look at what physical processes impact their system; what zooplankton are available for species dependent on their food type; document water column biology (zooplankton)	South Bering Sea; Aleutian Islands (wintertime)	Standard Package; extreme cold technology; biochemical genetic screening; tagging; remote sensing; ice breaker ships; Thermal Imaging; Nation Technical Means; aircraft; acoustic monitoring; biophysical moorings (winter); new sampling technologies	Standard Partners; Industry; Navy; US/Canadian/Russian Coast Guard; NSF; Arctic Logistics; BASC; VECO Corp.
343	Ecosystem - Extreme Environments - Vents, Seeps, & Volcanoes	Hydrothermal vents	Locate isolated biologic communities and sea floor mineral masses	Ingenstrem Depressions; scarps and related basins; many of the pull-apart basin located along the volcanic line west of Kiska	Standard Package	Standard Partners
166	Ecosystem - Shorelines to Ledges	Intertidal zones	Document biodiversity and taxonomy; identify and characterize; document archeology.	Aleutian Islands; Islands in Gulf of Alaska e.g. Shumagins; Kodiak Island Group; Alaskan Peninsula	Standard Package; via helicopters from ships and Alaska Peninsula; standard biological sampling; LIDAR; acoustic monitoring	Standard Partners; Cruise lines
157	Ecosystem - Slopes	Continental rise and the outer continental shelf, down to the abyssal floor plain	Document biological communities and geologic history; examine this record of continental climate	Arc of the Gulf; Gulf of Alaska continental margin; Bering Sea; e.g. at the base of the margin cutting the canyons	Standard Package; Suite of geological and biological sampling devices; backscatter data; seismic reflection	Standard Partners; Various Commercial Partners
148	Geology & Geomorphology	Documenting climate variability (Molnia)	500 million year record of global climate; need to examine it to look for variability	Molnia	Standard Package; high resolution geophysics; coring	Standard Partners; Various Commercial Partners
149	Geology & Geomorphology	Glaciers (Molnia)	How did the glaciers existing in the Bering Sea change over time?; explore environment created and released by retreating or advancing glaciers; identify and characterize these environments	Gulf of Alaska continental shelf between Cook Inlet to Canadian Border; southeast Alaska; Glacier Bay	Standard Package; high resolution geophysics	Standard Partners; various commercial partners

Alaska Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
165	Geology & Geomorphology	Plate boundary - strike slip system	Map and perform water column survey; identify and characterize biota	Icy strait - Canadian border to Alsek River; South of Icy Strait; Fairweather Fault; Yakutat Terrain	Standard Package; basic surveying tools	Standard Partners; Canadian Government (Earth Science Sector); Petroleum Corporations
158	High Resolution Bathymetry	Mapping	Collect hydrographic; bathymetric and tidal data - mean low and high water; document navigation hazards; and biota	Western and northern Alaska; Bristol Bay; Arctic Basin; Bering Sea; Bering Strait; Bering Sea (data gaps areas); North of Sag River; entire shoreline of Beaufort Sea; Cape Lisbourne	Standard Package; tide gauges; Backscatter processing; fathometers in shallow water; LIDAR	Standard Partners
173	Human Impacts	Hazard dumps	Determine location and chemistry of material; characterize these sites	Aleutians	Standard Package; hazard sampling techniques; underwater moorings	Standard Partners
161	Marine Conservation	Essential fish habitat	Map and inventory benthic habitats to gain knowledge and understanding impacts of essential fish habitats; candidate areas of protection	Pribilof Canyons; between Aleutians and shelf break	Standard Package	Standard Partners; fishing industry
178	Marine Microorganisms	Microbes in the Bering and Chukchi Sea	Microbiology and micro-zooplankton sampling; What are the abundant and important microbes and micro-zooplankton of the Bering and Chukchi Sea; gain knowledge of ecosystem health; understand long-term variability	Chukchi Sea; Bering Sea	Standard Package; specialized sampling and growth chambers; microscopy	Standard Partners
179	Marine Microorganisms	Microscopic interfaces	Explore unknown micro- / nano- environment; characterize it including information on microscopic interfaces of chemistry; microbiology (liquid-solid interface)	Shelf; shallow water	Standard Package; micro sampling; micro- and nano-technologies	Standard Partners

Alaska Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
180	Marine Organisms	Where do high latitude organisms go to spend winter	Support for designation of critical habitats	Polynyas - St. Lawrence; Sereniki; St. Matthew	Standard Package; biological and physical tools; benthic sampling; ice breakers; remote sensing; aircraft	Standard Partners; Industry; Navy; US/Canadian/Russian Coast Guard; Native Communities; NSF; Arctic Logistics; BASC; VECO Corp.
176	Ocean Resources - Energy & Minerals	Gas hydrates	Document interaction w/ ocean; Identify and characterize communities associated with them; Map distribution and location; Assess VAMP (Velocity Amplitude) Structures	Deep Gulf of Alaska; Beaufort; North Slope; Chukchi; Wrangall Island; Bering Sea Basin	Standard Package; seismic profiling; sniffers	Standard Partners
167	Sound in the Ocean	Characterize naturally occurring sounds	Listen to seismic acoustics; fauna acoustics; Marine mammals; and fish; Use acoustics to determine migration paths	Aleutians; SE Alaska; Aleutian Arc; Bering Sea	Hydrophones; observing system(s)	Standard Partners

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Alaska Region Exploration Targets of Interest

1. Adak Island (Aleutian Chain)
2. Bowie Seamount Chain
3. Aleutian Fore Arc
4. Arctic Basin/Ocean
5. Atka Island (Aleutian Chain)
6. Attu Island (Aleutian Chain)
7. Beaufort Sea (shoreline)
8. Bering Basin/Sea
9. Bering Strait
10. Bogoslof
11. Bristol Bay
12. Camden Bay
13. Cape Lisbourne
14. Chukchi Sea
15. Cook Inlet
16. Duke Island
17. Fairweather Fault
18. Glacier Bay
19. Gulf of Alaska (between Cook Inlet and Canada)
20. Haida Villages
21. Icy Bay
22. Icy Strait
23. Kiska Island (Aleutian Chain)
24. Kodiak Islands
25. Kodiak Seamount
26. Lynn Canal
27. Nome
28. Patton Murray Chain
29. Pratt-Welker Chain
30. Pribilof Canyon
31. Prince William Sound
32. Shumagins
33. Wrangell Island
34. Yakutat Terrain

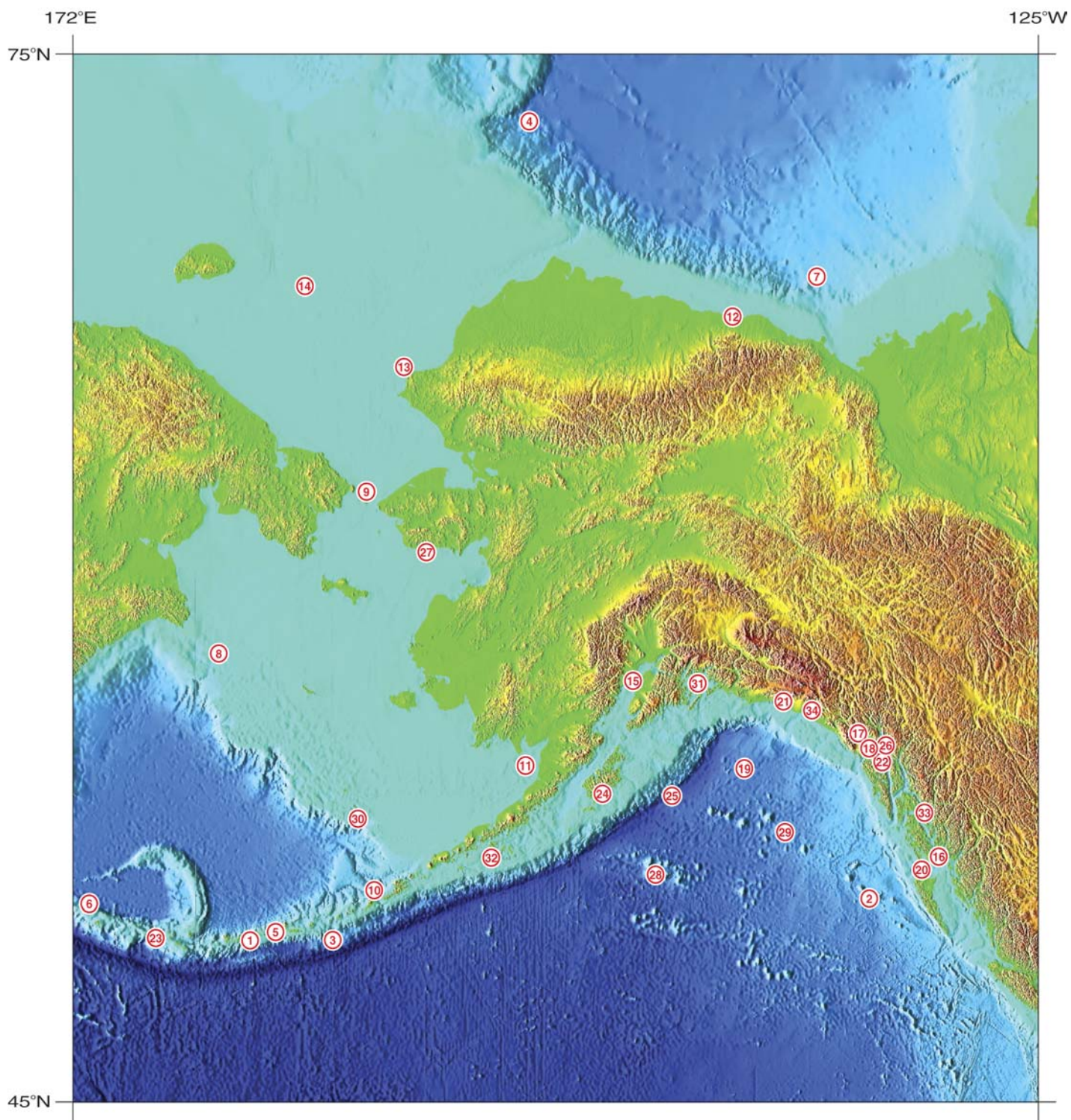


Figure 3-6. Alaska Region Exploration Targets of Interest

3.4.5 West Coast Region

Exploration targets of interest within the Monterey Bay National Marine Sanctuary received considerable attention during the West Coast region workshop. The participants focused on exploration of the entire water column and the benthic environment and included the need for observations down to a microbial scale. Exploration for archeological purposes was discussed and, like the Alaska region, included some attention to the use of local traditional knowledge. The identification and location of deep corals, including an assessment of potential threats to their health, were topics receiving noteworthy attention. The need for new technologies or methods for tagging gelatinous biota were discussed and included an examination of current experiments that tag parasites on the gelatinous host to allow tracking.

The participants discussed issues related to data management and outreach. The data management issue involved the turnaround time for release of data by a principle investigator. The group felt it was reasonable for metadata to be provided for distribution within 90 days of data collection. The participants agreed that more outreach needs to be done and pointed to the success of the unique and valuable outreach partnership between the Monterey Bay Aquarium Research Institute (MBARI) and the Monterey Bay Aquarium.

The West Coast region results are provided in Table 3-7. Exploration targets of interest nominated by participants are illustrated in Figure 3-7.

Table 3-7. West Coast Region Workshop Results

West Coast Workshop	
Standard Package: Class I/II Vessel with acoustic mapping; Dive capability (ROV/AUV/ Submersible) with imagery/video and sampling equipment; Precise positioning system; CTD; Dynamic positioning & bottom high resolution survey capability (not always needed for ops); Sensors dependent upon expertise with mission; High quality communications & internet	Standard Partners: NURP; NMFS; Fish & Game; Oceanographic institutions; Universities; UNOLS; Private foundations; Museum/Aquaria; Sea Grant; Private industry; MMS; International partners; State geological surveys; State Historic Preservation Office (SHPO); Canadian counterparts; Mexican counterparts; Educational outreach group; NMS; Navy; NOAA; NASA; NSF; Alliance for Coastal Technology (NOAA); USGS; USCG; NGOs

West Coast Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
237	Archeology	Ships (shipwreck) of importance	Mapping habitat; multidisciplinary effort; chemo/bio/geo	Workshop results and historical records. Determine location. Luckenbach (San Francisco); Montebello (off Cambria) possible tar issue; Pac Baroness (entrance of Santa Barbara Channel) bulk cargo of copper sulfate.	Standard Package; Mapping technology; chemical analysis; shipwreck integrity tools	Standard Partners
238	Archeology	Marine archeology/ human habitat	Historical records/archives; traditional knowledge; pick sites; document & remove; map (paleo shoreline); pick sites; doc & remove; look at mapping info from other missions then go to sites; develop strategy on where to look; location; photo documentation; controlled removal; habitat; climate	Develop strategy on where to look; Channel Islands; 140 m below sea level (old coastal level); Santa Barbara Channel; Baja California	Standard Package: high resolution imaging; sidescan; magnetometer; removal technology tools; laser imaging; saturation diving; mapping of shorelines; light sub-bottom profiling; laser linescan technologies to direct sampling; coring technologies	Insurance industry; EPA; Coast Guard; NMS; DOS; DOD; states; National Geographic; Discovery; Salvage Industry; (Ole Varmer - NOAA NOS Shipwreck Attorney)

West Coast Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
239	Marine Organisms	Use of pelagic and benthic environments by economically/ecologically important species; by Rare Species	Life history; migration patterns; habitat; population; distribution and abundance; environmental properties; Track location of critter; Beacon to uniquely ID individual; Attach Critter Cam; fronts/eddies - use remote sensing to ID areas; Listen and observe sounds; LIDAR to monitor; observe; track fish	Basin wide; continental shelf; oceanic; existing protected areas; also see offshore productivity list; fronts and eddies	Standard Package; Satellite tag; data storage tags; satellite remote sensing (benthic and passive); acoustics (passive and active); genetic tools; aircraft; human observation; CODAR; Tagging technology; Critter Cam; LIDAR	Standard Partners; NPS; Military; biogeochemistry academic community; international partners; Stanford Hopkins Marine Station; CoML; Moss Landing Marine Laboratory; Packard Foundation
256	Benthic Environment	Deep sea floor	Knowledge of the deep sea floor; surveys via AUVs; sweeping water column; detailed survey then expand; biosphere at seafloor; benthic community; crust & microbial communities; i.e. all deep sea floor communities	Bottom mixed layer to sea floor; deep water North Pacific on coast	Standard Package; Image recognition and software; HDTV & holographic; improving control systems for ROVs - adapt to situations; software development; flow cytometers for microbe levels (refinement in technologies); higher flow sampling for midwater communities; navigation; nested acoustics techniques; continuous capability; capturing particle flux; long-term & long-standing observatories; coring; genomics on a chip	Standard
336	Benthic Environment	Benthic invertebrates	Abundance of species occupying sub-tidal rock substrates in Washington and Oregon, especially benthic invertebrates	Rock substrates in Washington and Oregon	Standard Package	Standard Partners
236	Corals - Deep Water	Deep water corals	Locate; map; characterize and ID; assessment of threats - existing and emerging; other species supported by habitat	Rocky bottom areas; low sedimentation rates; high currents - below trawl depth. 1-2 KM priority. Monterey Canyon; Astoria Canyon Flanks of seamounts (see above)	Standard Package; deep camera tows; further development of laser technology; lowlight cameras in rough terrain; slow moving steady AUVs	Standard Partners

West Coast Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
231	Ecosystem - Abrupt Topography	Banks; fracture zones; subduction zones; canyons; sea mounts	Mapping; subsurface information; sub bottom profiling; biosampling; currents; temperature; chemical description; cores to sample the microbial activity	Cordell Banks; Tanner/Cortez Bank; Oregon Bank complex; Southern California Border Banks; Mendocino; Molokai; Canyons: Big Sur Canyon Complex; Pt Conception complex; Juan de Fuca; Rogue Canyon; Eel River Canyon; Quinalt Canyon; Santa Cruz Canyon; South American canyons (re: strike slip transition); Davidson; Guide; and Pioneer Seamounts; and Gumdrup and Taney Seamounts; Brown Bear and Cobb Seamounts; Bowie Seamount Chain	Chemical sniffers; NMR; genetic fingerprinting; acoustic mapping; long term chemical sampling (e.g. OsmoSamplers)	Standard Partners
251	Ecosystem - Abrupt Topography	Biological oasis hot spots	Close in seamounts then remote seamounts; survey triage of hot spots; different tactics for each hot spot; discover; inventory biota; explore; identify processes; find new areas	Seamounts; canyons; upwelling; ocean frontal zones; river plumes; seafloor hydrothermal vents	Standard Package; Imaging - HDTV & holographic; nested acoustics techniques; continuous capability; capturing particle flux; long-term & long-standing observatories; coring; genomic on a chip; generation of sampling technology (give 100x more data) ; genetic markers on AUVs; remote sensing technology on AUV; real time capability; chemical sensor; PSATS; electronic tags; <20 microns technology very important; anecdotal fisherman reports; "Ready 5" capability	Fishing industry (Russians; etc.); MMS

West Coast Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
254	Ecosystem - Canyons	Canyon systems; gullies (physical; chemical; biology systems)	Hyperpicnal flows; observing systems for long term; investigate submarine rock flows; turbidity currents; internal waves; bridge from shelf to deep sea; develop proxies of variability over time in sediments	West coast; Big Sur Canyon Complex	Standard Package; Forward scatter acoustic techniques; equipment survivability cabling systems; need hardened sensors; "instrumented rock"; long-term instruments that can survive in the canyon environments; temporal exploration; physical ocean modeling	Cable companies; USACE; Coastal States Organization (CSO)
241	Ecosystem - Extreme Environments - Vents, Seeps, & Volcanoes	Microinvertebrate assessments	Microinvertebrate assessments e.g. kelp forest assemblages and soft habitat; microbial ocean; assemblages; interactions; predator/prey relationship	California kelp forests; soft benthic habitats out to 60' (20-60' water depth)	Fiber optics; basic archeological sampling; species identification	Standard Partners
242	Ecosystem - Extreme Environments - Vents, Seeps, & Volcanoes	Microbial	In situ sampling and genomic identification & chemistry; particle counter for small particles - size fractions; cameras - is there a good proportionality ratio that is pretty universal; microbial assemblages; characterization; taxonomy; role they're playing in larger ecology; bio/geo/chemical processes; bioactive compounds	Could go anywhere and make fundamental discoveries i.e. polar oceans; polluted and non polluted locations to compare microbial assemblages; Throughout water column including the substrate	Moorings; smaller vessels; genomic; chemical analysis tools; In situ genetic sampling	Biomedical industry; EPA; Fish and Game; local and state health departments; Surfriders
243	Ecosystem - Extreme Environments - Vents, Seeps, & Volcanoes	Seeps	Mapping; subsurface information; sub bottom profiling; biosampling; currents; temperature; chemical description; cores to sample the microbial activity	Between Heceta Bank and Hydrate Ridge; along alluvial washout of Monterey Canyon.	Chemical sniffers; NMR; genetic fingerprinting; acoustic mapping; long term chemical sampling (e.g. OsmoSamplers)	Standard Partners
244	Ecosystem - Extreme Environments - Vents, Seeps, & Volcanoes	High temperature hydrothermal environments	Relatedness between sites	West coast of North and South America (fragments of the Farallon Plate) - interaction of a ridge with a continental margin); opportunity to look thru genetic mutations; how long ago were things isolated?	ROV sampling tools; physical oceanographic sensors; Larval sampling tools	Standard Partners

West Coast Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
245	Ecosystem - General	Chemistry; physics; geology	Biogeographic cycling; inputs/outputs cycling	Needs to be done in the context of the other identified exploration needs	In situ chemical sensors; satellite data; remote sensing	Standard Partners
229	Ecosystem - Shorelines to Ledges	Continental shelf	Benthic; Marine Protected Area; proposed Marine Protected Areas; cables; then go observe; general baseline mapping (high resolution); habitat substrate; geo/bio/chem; current; temperature; ID and characterize	West Coast; existing protected areas; proposed Marine Protected Area cable routes; heavily trawled areas; areas of heavy coastal/urban development; same locations as above; also untouched areas	Standard Package - multibeam; bioacoustics tech; ADCP; seismic profiling; remote sensing; observatory approach; standard regular remote sampling techniques; temporal/seasonal sampling tools; higher resolution remote sampling; processing/visualization tools	Standard Partners; states; sanctuaries; NOS; NOAA hydrographic program
252	Ecosystem - Shorelines to Ledges	Nearshore habitat; archeological paleoclimate area	Habitat on nearshore (shelf and slope); Archeological paleoclimate area; targeted anthropogenic impacts; high definition visual surveys; look for arch. sites of previous civilization; look for deeper wrecks; understanding of flows of chemicals; fisheries; understanding biological hot spots; sediment transport; physical; current flow interactions; discover history influences; understanding margin marine boundary layer	0-1000m depth; 0-100m transport	Standard Package; sidescan; magnetometers; sub-bottom profiling; laser line scan; range gating system; geochemical measuring systems; geology system (porosity); sediment transport system (suspension); generation of sampling technology (give 100x more data); genetic markers on AUVs; remote sensing technology on AUV; etc; real time capability; chemical sensor	Cultural resource organizations; Naval Oceanographic Office; oil companies; museums; NGOs; National Cultural Archival Organization; States Historical Preservation; tribes/islanders; ecotourism
253	Episodic Events	Plate scale to mesoscale	Plate scale to mesoscale observatory; long-term understanding of episodic events; gyre scale; absorption of CO ₂ ; needs thorough mapping effort; collaborative effort; new ways to do oceanography; understanding fluid flux productivity of subduction zones; sources of interplanetary life	Observe 50-70km	Large logistics; huge communications requirements; fiber optic observatory	Telecommunication industry; oil/gas industry; Canada; Germany; etc.

West Coast Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
257	Marine Organisms	Pelagic animal movement and orientation	How animals find guideposts in the open ocean; animals as ocean explorers; how the populations succeed; behavior patterns; interactions with ocean structures; use of habitat; range and navigation	Basin scale Pacific Ocean; eastern North Pacific Ocean; entire water column	Pop-Up Satellite Archival Transmitters(PSATS); archival tags; acoustic network tracking; active acoustic tracking; ARGOS; imaging systems	University; electronics industry; CoML; fishermen (recreational & commercial); conservation groups
258	Ocean Resources - Energy & Minerals	Crustal processes	Hydrates; fluids (seawater and gases); Crustal processes that affect fluid flow; determination of location and volume of hydrate resources; classification; chemistry; fluid flow; subduction zone; hydrothermal processes; microbial populations and dynamics; fluid pressure and quantification of flow	300m-3km (maybe more) depths; emphasize below 1000m; EEZ; outcroppings; plate scale; active seeps; middle of plates	Standard Package; Acoustic mapping; higher resolution chemical sensors	Standard Partners
230	Pelagic Environment	Midwater	Species diversity; ID and characterize; food web; link between upper water and benthic water; how the midwater functions in this role; evolutionary relationships; geographic relationships; connectivity	Gross global sampling (have some info on Japan and Monterey Bay)	Standard Package; Suction samplers; insulated compartment; observation & tracking technology; large samplers (new tech); collection tech; AUVs that follow; critters (new tech); Genetic tools; ROVs for filming; sampling and observing behavior; HDTV video very useful; establishing strobe frame photography at some time series sites to get understanding of change of abundance	Standard Partners; HBOI; Canada; MBARI; JAMSTEC (Japan); National Geographic Society; Discovery Channel; Monterey Bay Aquarium; other aquaria

West Coast Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
250	Pelagic Environment	Deep sea water column	Knowledge of the deep sea water column (largest biomass on planet); biota - what organisms exist (distribution; abundance; dynamics)	Bottom mixed layer to sea floor; deep water North Pacific on coast	Standard Package; Image recognition and software; improving control systems for ROVs - adapt to situations; software development; flow cytometers for microbe levels (refinement in technologies); higher flow sampling for midwater communities; nested acoustics techniques; continuous capability; capturing particle flux; genomic on a chip	Standard partners
255	Pelagic Environment	Euphotic zone productivity	Productivity of ocean in euphotic zone; understanding life stages of organisms; discover new members; <20 microns (includes viruses; parasites); spatial structures (scales); need balance equation	Euphotic zone; Central Gyre; Monterey Bay	Standard Package; new genetic methods; new techniques for energy flow thru life form systems; genetic probes; active fluorescence; in-situ visualization; observation techniques	Standard Partners; Russia; Poland; agriculture companies; commercial fisheries; remote sensing (NASA)

West Coast Region Exploration Targets of Interest

1. Astoria Canyon
2. Coquille Bank
3. Cordell Bank
4. Davidson Seamount
5. Eel River Canyon
6. Guide Seamount
7. Gumdrup Seamount
8. Heceta Bank
9. Johnston Seamount (not on chart)
10. Juan de Fuca
11. Mendocino
12. Monterey Bay
13. Monterey Canyon
14. Pioneer Seamount
15. Pt Conception
16. Quinault Canyon
17. Rogue Canyon
18. Santa Barbara Island (not on chart)
19. Santa Barbara Channel (not on chart)
20. Santa Cruz Canyon (not on chart)
21. Stonewall Bank
22. Sur Canyon
23. Taney Seamounts
24. Tanner/Cortez Bank (not on chart)

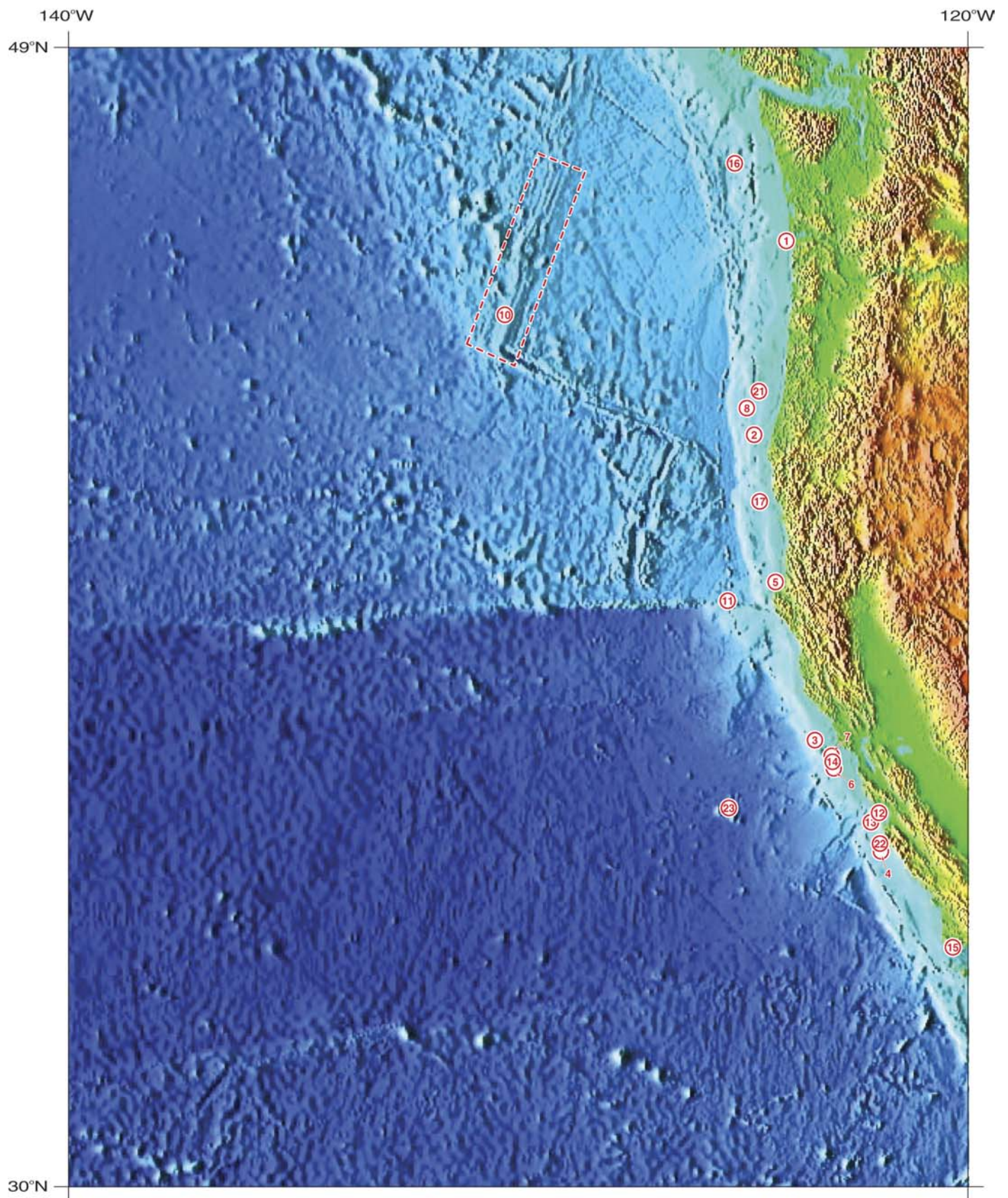


Figure 3-7. West Coast Region Exploration Targets of Interest

3.4.6 North Atlantic Region

A large contingent of government and academic representatives of the region attended the North Atlantic workshop in Groton, Connecticut. This group identified a wide spectrum of needs ranging from the inventory of living marine resources in the near shore environment to exploration of areas of abrupt bottom topography with an emphasis on the relationship between the geomorphology and the abundance, diversity, and novelty of biological inhabitants. Regional marine archeological needs were of interest within the workshop and were well represented by knowledgeable participants.

Additional exploration needs identified by these participants included the study of the transitional areas near the continental shelf, the abundance, location, and diversity of corals and fish, and exploration of gas hydrates provinces. Participants recognized the need for high-resolution bathymetric mapping but sought assurances that mapping would not be emphasized by the OE program at the expense of other ocean exploration needs. The attendees also examined the increased need for expertise in taxonomy of marine resources and possible solutions for meeting the demand for these resources.

Results from the North Atlantic workshop are provided in Table 3-8. Exploration targets of interest nominated by participants are illustrated in Figure 3-8.

Table 3-8. North Atlantic Region Workshop Results

North Atlantic Workshop	
Standard Package: Class I/II Vessel with acoustic mapping; Dive capability (ROV / AUV / Submersible) with imagery / video & sampling equipment (Not Only ROV / AUV / Sub); Multi-beam; ADCP; Precise position system; Outreach capability; Education component; Deep Standard Package: Class I/II Vessel with acoustic mapping; Dive capability (ROV/AUV/Submersible) with imagery/video and sampling equipment; Precise positioning system; Navigation mapping technology; Coastal Standard Package: Class III/IV Vessel; Wet diving chamber/compressor; DMT; Dive master; Acoustic mapping; sidescan; Precise positioning system; Navigation mapping technology	Standard Partners: NURC; Sanctuary Program; NMFS; USGS; Sea Grant; Institute for Exploration (IFE); NOS; NURP; UNOLS

North Atlantic Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
183	Archeology	Regional archeological assessment; cultural resources, chronology site ID	Distribution of wrecks; structures; aircraft; items of cultural impact; dump sites; identify all cultural resources with in a region; characterization of bio/ geo/chemical at sites	Regional assessment sampling strategy needed (sites with a range of maritime landscapes); regulated areas	Standard Package; High Resolution Survey – SUBs / ROVs /AUV's; magnetic Acoustic sensors	USACE; State Governments; Academia; Aquariums; not-for-profit entities; USCG; Navy; commercial interests
187	Archeology	Character of deep water archeological sites	Wrecks; structures; cultural resources; Priority to older targets; local biota	Target identified by broader area of survey - Virginia Capes;	Standard Package; deep water sub's ROV's / AUV's / imagery & video; remote manipulator; magnetic	Standard Partners
204	Archeology	Shipwrecks (5-10K off New England)	Location; ID & characterize	Close to shore; fishing banks (Georges Banks; Jeffrey's Ledge; Gulf of Maine; shipping lanes - close to shore; "right down the list"	Standard Package; magnetometer; archival technologies	Standard Partners

North Atlantic Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
205	Archeology	Submerged prehistoric sites	Location; ID & characterize; which are still intact; paleogeography; paleo communities; paleo biological assemblages	Shallower than 120m isobaths; near major drainages; coastal embayment; areas of intense fishing activity	Standard Package; Geologic mapping; coring; sub-bottom profiling; sidescan; magnetometer; AUV; Also local knowledge	Standard Partners
222	Archeology	Shipwreck aggregation sites	Not well documented	Nantucket Shoals; Hatteras; Graveyard of Atlantic; Stellwagen Bank; Boston Harbor entrance; Long Island Sound; Buzzards Bay; Narragansett Bay; entrance to Chesapeake Bay; outer Cape Cod; Casco Bay; & New York Harbor	Standard Package	Standard Partners
190	Benthic Environment	Knowledge of deep benthic community	Characterize biology and geology; bottom interactions; ecology dynamics; deep cold corals	Topographic feature of interest	Standard Package; deep submersibles; observations; AUV's; acoustic imaging; chemical sampling techniques	Standard Partners
215	Benthic Environment	Abyssal plain	Not well documented	South of Oceanographer & east of Norfolk Canyon	Standard Package	Standard Partners
195	Corals - Deep Water	Knowledge of deep and or cold water corals	Deep cold corals; location; health; bio/geo/chemical environment	Bear Seamount; Oceanographer Canyon; Lydonia Canyon; Nova Scotia & New Brunswick	Standard Package; Magnetic Sensors; sub-bottom profilers; chemical sensors; "tailored" AUV/ Sub/ ROV's	Standard Partners
193	Currents & Water Masses	Knowledge of physical & biological processes near fronts; eddys, warm and cold rings	Intersections between layers; relationships to biota; air-sea patterns / interactions; impact of bottom boundary; archeological application; magnetic sensors; data mining; bottom mapping & characterization capability; new sampling protocols; multi-line arrays and multi-sensor arrays	Gulf Stream; Labrador; Gulf of Maine; Long Island Sound	Standard Package; remote sensing; fixed sensors; sensor arrays; AUV's; magnetic sensors; data mining; bottom mapping & characterization capability; multi-line/sensor arrays	Sea Grant Program; Aquariums (Maritime Aquariums @ Norwalk; Mystic, Baltimore, & New England...)

North Atlantic Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
219	Ecosystem - Abrupt Topography	Gravel cobble bottom - continuous features vs. discrete	Not well documented	Corsair; Oceanographer; & Hydrographer Canyons; Stellwagen & Georges Bank; Great South Channel; Jeffrey's Ledge	Standard Package	Standard Partners
213	Ecosystem - Banks & Basins	Banks	Not well documented	Stellwagen & Georges Bank; Nantucket Shoals; Tillies & Browns Banks; Banquero & Emerald Banks	Standard Package	Standard Partners
214	Ecosystem - Basins & Banks	Basins	Not well documented	East & west Tillies Basin; Georges; Jordan; Wilkinson & Stellwagen Basins	Standard Package	Standard Partners
217	Ecosystem - Basins & Banks	Gravel windows - sediment disturbed & gravel exposed	Not well documented	Stellwagen Basin	Standard Package	Standard Partners
221	Ecosystem - Basins & Banks	Glacial scoured areas	Not well documented	Northeast Stellwagen Bank; Jordan Basin	Standard Package	Standard Partners
192	Ecosystem - Canyons	Knowledge of submarine canyons	Transport mechanism; habitat diversity; sediment transport; nutrient transport	Continental Margin; Hudson Canyon; Lydonia Canyon; Varied Geomorphology; Gradient of Human influence	Standard Package; acoustic mapping; non-destructive investigations; robotic manipulation; sub-bottom profiling; tools for sample & artifact recovery; interpretation tools; spectral analysis tools; data mining; laser line scan; Critter Cams	Standard Partners
211	Ecosystem - Canyons	Submarine canyons	Not well documented	All major canyons e.g. Georges Bank canyons and mid-Atlantic canyons e.g. Oceanographer; Veatch; Baltimore; Norfolk; and Wilmington Canyons; Pueblo village communities and the canyon axis; boulder fields; slip stone outcrops	Standard Package	Standard Partners
220	Ecosystem - Channels	Channels	Not well documented	Great South Channel; Northern Channel	Standard Package	Standard Partners

North Atlantic Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
186	Ecosystem - Seamounts / Ridges	Knowledge of impact of Seamounts on ocean dynamics; also other abrupt topography	Ocean currents; ecosystems; biogeography; biodiversity	Bear Mount; New England Seamount chain; Mid Atlantic Ridge; Cashes Ledge; other small features	Standard Package; Sub/ ROV's/ AUV's video imagery; sampling systems; acoustic mapping	Standard Partners
210	Ecosystem - Seamounts / Ridges	Seamounts	Systematic documentation	All seamounts e.g. New England seamount chain	Standard Package;	Standard Partners
182	Ecosystem - Shorelines to Ledges	Knowledge of near-shore environments	Inventory; characterize & measure; habitats; bathymetry; bio/geo/chem of shallow water and processes near fronts - colds corals; archeology;	Coastal New England	Shallow water mapping; sediments; remote sensing; in turbid water; small vessels; autonomous vehicles; aircraft archeological application; magnetic sensors; data mining; bottom mapping & characterization capability; new sampling protocols; multi line arrays and multi sensor arrays	USACE; State Governments; Academia; Aquaria; not-for-profit entities; USCG; Navy; commercial interests
212	Ecosystem - Shorelines to Ledges	Ledges	Not well documented	Jeffrey's Ledge; southern Cashes Ledge; Fippennies; Platts; all along the coast of Maine e.g. smaller coastal ledges	Standard Package	Standard Partners
200	Ecosystem - Slopes	Study transitional areas between biogeographic areas & shelf slope regions	Species distribution and ranges; species dynamics; tropic interaction; invasive; patterns	Georges Bank; Cape Hatteras; 350m isobaths; any biogeographic breaks	Standard Package	Standard Partners
216	Ecosystem - Slopes	Slopes (600 to 4000 ft)	Not well documented	Slopes adjacent to ID canyons or seamounts	Standard Package	Standard Partners
207	Episodic Events	Observing episodic events & rare species e.g. storms, blooms	Short-term events - frequency; strength; intensity; impact; magnitude; compare & contrast	Marine Protected Areas; abrupt bottom topography; areas representative of a range of topographies e.g. ledge vs. flat bottom; e.g. Gulf of Maine; marine mammal habitat	Camera; observation technology	Standard Partners

North Atlantic Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
198	Extreme Environments - Vents, Seeps & Volcanoes	Chemosynthetic communities (subsurface - down several km): hydrate vents, seeps and vent communities	inventory and characterize; isolated ridge system; new biota; larger geographic context; physical & chemical systems	Mid-Atlantic Ridge	Standard Package; multibeam geophysical techniques; sampling techniques; satellite imaging; towed vehicles; subs; AUV's look at new technologies	Standard Partners
199	Extreme Environments - Vents, Seeps & Volcanoes	Knowledge of micro-organisms in the deep sub-bottom	Sea floor Biosphere	Deep water	Standard Package; deep sampling technology; Ocean Drilling Program (ODP)	Standard Partners
196	Geology & Geomorphology	Knowledge of physical processes related to geomorphology	Mass-gravity movement; turbidity flows; hydrate beds; slope instability; chemical analysis	US Continental Margin; Hudson Canyon region;	Standard Package; Sub/ROV/AUV imagery; seismic survey; acoustic mapping	Standard Partners
218	Geology & Geomorphology	Protected paleo-shorelines	Not well documented	South of Long Island & Nantucket; Gulf of Maine; Weymouth	Standard Package	Standard Partners
197	Human Impacts	Knowledge of impact of fishing on ocean regions	Health of benthic habitat; CoML; archeological impacts; history of technology	Grand Banks; Georges Bank; Gulf of Maine; Area where fisheries are expanding into	Standard Package; Sub/ ROV's/ AUV's video imagery; sampling systems; acoustic mapping	Standard Partners
188	Marine Organisms	Distribution of migration & abundance of large, highly mobile biota	Marine mammals; giant squid; other unknown species; large deep water sharks	Beyond continental margin	Survey techniques; tagging & tracking; acoustic imaging; AUV imaging	Standard Partners
194	Marine Organisms	Distribution migration & abundance of gelatinous plankton	Pelagic Plankton; Vertical migration patterns	Seamounts; canyons; along shelf margin	Sampling technology; AUV's	Standard Partners

North Atlantic Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
201	Marine Organisms	Ecosystem engineers and foundation species (corals, tile fish)	Abundance; location; diversity; new species; establish patterns; expertise in taxonomy of marine resources; education	For corals: shelf break; canyons; edges of basins; seamounts; deep and inaccessible; for mussels: Grand Manan Basin; upper slope environment	Standard Package; Plus time series observations; national & international standards; collections management; scholarship programs; training in fieldwork for applicable disciplines; sponsoring existing entities with expertise; expert system can help enable; graduate fellowship programs; establish positions (FTE's) for populations by existing professionals; service academies; establish accommodating university policies; establish separate; collaborative institute	Standard Partners; Educational Institutions: Sea Grant; Museums; Non-Profits
203	Marine Organisms	Novel feeding relationships		Coastal regions near algal beds; offshore basins; depositional environment; marine mammal hotspots	Sampling & stable isotope analyses for food pathways; remote sensors for marine mammals; Critter Cam	Standard Partners
208	Marine Organisms	Observing rare species	For fish & marine mammals: migratory & threatened species e.g. location of bottleneck dolphins; unusual spawning; general behavior	Marine Protected Areas; fish aggregation areas e.g. Stellwagen Bank; ledges; fishing grounds; plane used by marine animals	Cameras; observation technology	Standard Partners
202	Ocean Resources - Bioprospecting	Bioprospecting	Biotech industry	Areas of high diversity; abrupt topo changes; deep within our region and tropical;	Bioprospecting technology; standard sampling technology that capture and keep specimen alive	Standard Partners
184	Ocean Resources - Energy & Minerals	Knowledge of gas hydrates provinces	Process of gas hydrates potential resources effects of gases on chemosynthetic communities; climate impacts; slope quality	US EEZ; Hudson Canyon Region; (fiber Optic Hub)	Submersibles/ROV's; sampling methods	Standard Partners

North Atlantic Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
209	Ocean Resources - Energy & Minerals	Non-biological resources (note: this should not be primary focus of OE)	Minerals; oil & gas; hydrates; location; occurrence; stability; mixed aggregate	U.S. EEZ	Archive data	Standard Partners
189	Pelagic Environment	Deep pelagic realm	Characterize; biology dynamics	Sea mount & canyons along the continental shelf; greater than 1000 meter depth	Standard Package; deep submersibles; observations on a broader scale; AUV's; acoustic imaging; chem./bio sensors	Standard Partners
206	Pelagic Environment	Pelagic realm - surface to deep sea	What's there? Species diversity issues; location; ID and characterize; function; what's there to exploit & conserve; patterns	Beyond shelf break e.g. Oceanographer Canyon and south	Standard Package; submersibles; ROVs; acoustics; sampling tools to collect gelatinous organisms	Standard Partners

North Atlantic Region Exploration Targets of Interest

1. Atlantic Continental Margin
2. Baltimore Canyons
3. Banquero Bank
4. Bear Mount
5. Browns Bank
6. Buzzards Bay
7. Casco Bay
8. Cashes Ledge
9. Chesapeake Bay
10. Corsair Canyon
11. Emerald Bank
12. Fippennies Ledge
13. Georges Bank
14. Grand Banks
15. Great South Channel
16. Hudson Canyon region
17. Hydrographer Canyon
18. Jeffrey's Ledge
19. Jordan Basin
20. Lydonia Canyon
21. Mid-Atlantic Ridge (not on chart)
22. Nantucket Shoals
23. Narragansett Bay
24. New England Seamount Chain - six volcanic seamounts located off Georges Bank: Bear, Mytilus, Physalia, Picket, Retriever, and Buell
25. Norfolk Canyons
26. Oceanographer Canyon
27. Platts Bank
28. Pueblo Village Communities
29. Stellwagen Basin
30. Stellwagen Bank
31. Tillies Bank
32. Washington Canyons
33. Wilmington Canyons

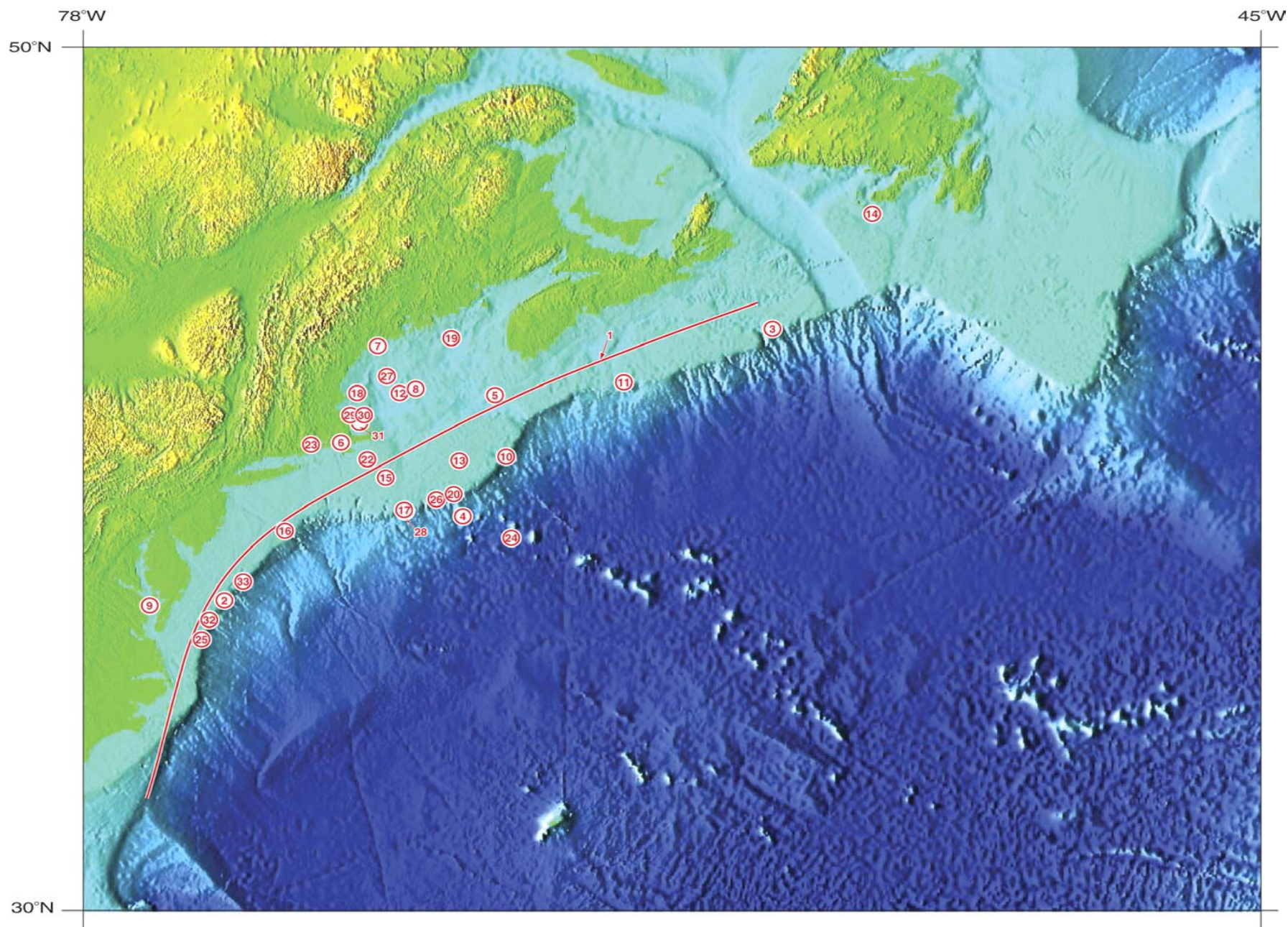


Figure 3-8. North Atlantic Region Exploration Targets of Interest

3.4.7 Great Lakes Region

Participants in the Great Lakes region workshop consisted mainly of representatives from educational institutions and local government. One of the principal interests of the group was exploration of seasonal change, species change, feeding rates, and identification and characterization of transitions occurring in represented biota. This interest was labeled as the discovery and understanding of seasonal change in “one cubic meter of water.” The group emphasized the need to understand the interactions between different biota based on the lake origin and species biodiversity. Exploration of the influence of surface and benthic storms on the distribution of nutrients biomass and currents was also discussed.

The workshop participants felt that additional efforts should be made in archeological survey to locate and document submerged cultural resources such as shipwrecks, ancient communities, and paleo-shorelines as a precursor to the management and preservation of these resources.

Additional discussions centered on the importance of the Great Lakes as a reservoir for fresh water. Participants talked in length about the value in exploring the world’s largest lakes (based on size) and comparing their biodiversity and genetic connectivity to the Great Lakes. The group proposed using the closed system of the Great Lakes to develop and prototype oceanographic models. They pointed out that this application would provide fewer logistical and resource challenges when compared to the open ocean explorations. Attendees pointed out the lack of high resolution maps for locating unique geological features (and habitats) including karsts, ring depressions, and ridge systems.

The group stressed the importance on understanding the Lakes during the winter when large areas are ice covered. Exploration under the ice in winter has been limited—similar to the Alaska region—and as a consequence the impact of ice cover on ecosystems and habitats is generally unknown.

Several participants felt that the Great Lakes are often overlooked in relation to ocean areas and that people living in the central U.S. are not as connected to the oceans. Projects involving the Great Lakes were also viewed as a method for reaching out and connecting with this constituency. Several participants discussed the need for a more

coordinated outreach program. One idea was the allocation of a Class I vessel as the lead ship for a multi-ship exploration expedition. Other methods included the pooling of efforts among academia, local government, and industry to raise awareness among K-12 students and the public.

Results from the Great Lakes region workshop are provided in Table 3-9. Exploration targets of interest are illustrated in Figure 3-9.

Table 3-9. Great Lakes Region Workshop Results

Great Lakes Workshop	
Standard Package: Class I/II/III/IV Vessel with acoustic mapping; Dive capability (ROV / AUV / Submersible) with imagery / video and sampling equipment; Precise positioning system; Walk-in cold room (4 degrees); Sea water system; Flux / aerosol / optical / meteorological sampling system	Standard Partners: EPA; Great Lakes Environmental Research Laboratory (GLERL); Ohio State University; Grand Valley State University; Canadian Center for Inland Waters; Canadian Dept of Defense & Coast Guard; Great Lakes WATER Institute; University of Michigan; Large Lakes Observatory; Michigan Tech; USGS; Coast Guard; University of Toronto; Illinois Natural History Survey; Departments of Natural Resources; NASA; WHOI; NSF; HBOI; National Geographic; Navy; USACE

Great Lakes Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
274	Archeology	Cultural resources; paleo-archeology of basin and human interactions -	Identify shipwrecks; Submerged shorelines; paleolake lines; ID sites; location; archeological documentation	All the Great Lakes basin wide; Green Bay; Saginaw Bay - Deep Water; Nearshore Karst features; Straits of Mackinaw Island; Submerged river mouths; Paleolake levels	Standard Package; sea water systems; predictive modeling; sidescan sonar; better/faster multibeam systems	Standard Partners
281	Archeology	Archeological survey and documentation	Location; documentation; evolution of marine technology; 19th century; effects on biology (good time measurement); influence of currents; also look at known wreck sites; broad based survey; then document important sites; search for existing data then document sites (model storm data)	Throughout Great Lakes; deep water; Lake Michigan; Thunder Bay (already have resources) Lake Champlain; Lake Superior; Death's Door; ports; Keweenaw Peninsula; Nearshore Karst features; Straits of Mackinaw; submerged river mouths; paleo-lake levels	Standard Package; technical divers; acoustic/laser vision system; magnetometer; modeling lake level studies and Interactive (w/ public) cameras; ROVs; multibeam; sub-bottom profilers; magnetometer; LIDAR; deep diving cold water diving; active acoustics; moored sensors & instrumentation; time lapse video; divers (SCUBA); reef design	East Carolina University, museums, historical societies, industry, philanthropy, Thunder Bay National Marine Sanctuaries, Office of Naval Research; Smithsonian; academia, Native American groups; University of Waterloo, Fish & Wildlife Service, tourism, recreational divers, University of Windsor

Great Lakes Workshop Results

ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
293	Artificial Habitats	Artificial reefs	Recruitment; deterioration of cultural material; environmental effect; new vs. used; lab	Artificial reef sites e.g. not too much fishing or commercial activity	Standard Package; Moored sensors & instrumentation; time lapse video; divers (SCUBA); reef design; Active acoustics	Standard Partners; industry; Department of Natural Resources (DNR); University of Waterloo; Fish & Wildlife Service; tourism; recreational divers; University of Windsor
275	Benthic Environment	Benthic communities - "Things that live between the rocks"	Limited sampling of difficult areas; deep reef systems; out crop reefs; Identify & characterize interaction; effects of exotics; impact of fisheries; compare w/ oceans; food web	National & International; Large Lake Areas; Lake Superior; compare with Chesapeake Bay and Gulf of Maine	Miniaturized exploration / sampling techniques; fiber optics & subs; ROV's; AUV's; dynamic positioning systems; small cameras & fiber optics; sucking mechanisms; different type of new technologies for sampling techniques for heterogeneous area; sensors with ability to describe the physical substrate in three dimensional sense; long term video observation platform; time lapse cameras	Standard Partners, Camera Manufacturers; SIO; industry (esp. finances - power plants, fishing, fishing support); boating industry; Sea Grant Extension (outreach & funding); Jason Project
283	Benthic Environment	Benthic communities	ID & characterize interaction; effects of exotics; impact of fisheries; compare w/ oceans; food web	Lake Superior; compare with Chesapeake Bay and Gulf of Maine	Standard Package; ROVs; Subs; sampling; AUVs; acoustic scanner; long term video observation platform & time lapse cameras	Standard Partners; SIO; industry (esp. finances - power plants, fishing, fishing support); boating industry; Sea Grant Extension (outreach & funding); Jason Project

Great Lakes Workshop Results

ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
271	Boundary Fluxes - Air/Sea	Linkage in the atmospheric forcing function	Forcing functions in atmosphere; air/sea interaction for the exchange of gas mass constitutes; across all lakes; temperature; current; wind speed; barometric pressure; real time chemical composition (monitor 5 places in one of the large lakes; see how lake responded over two years and choose detailed location and study eddies and zooplankton modeling); application for marine boundary levels influences; different processes to study and couple to ocean processes cores and eddy's (rings)	Ten largest lakes in the world; Lake Michigan (start where there are problems); need to be strategically positioned; Lake Champlain; Yellowstone Lake then translate atmosphere studies techniques for application into the ocean environment	Standard Package; Buoys; ADCPs; various sensors; mass spectrometer; wireless comms; real-time web access; instrumented moorings; drift buoys; instrument arrays; acoustic imaging; sediment traps New Measurement techniques (RADAR or LIDAR)	Standard Partners
294	Boundary Fluxes - Air/Sea	How climate varies in space & time	Climate Change on Timescales of Decades to Millennium	African Rift Lakes; other large lakes of tectonic origin	Drilling; Heave compensation and dynamic position or deep water anchoring	Standard Partners
288	Boundary Fluxes - Basins	Carbon cycling in lakes	Carbon cycling; primary productivity; Carbon accumulation; Carbon consumption; compare among lakes	Lake Superior; Lake Michigan vs. other lakes	Standard Package; AUVs; primary prod techniques; sediment traps	Standard Partners
272	Currents & Water Masses	Discover new bio / geo /chemical pathways (distribution in the physical sense)	Identify pathways for compounds	Least likely place	Indicator compounds exploration; measurement systems; platforms for opportunities; next generation of "FLIP"; smart sensors; swath vessel; remote sensing; super computer	Navy, Energy Industry, Marine Transportation; National Weather Service; Canada

Great Lakes Workshop Results

ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
279	Currents & Water Masses	Coupling of modeling and measurements; sample strategy/ bio / currents / atmosphere models - models can drive questions researchers to answers	Areas of gradients (where do you put the resources) at biologically dynamic areas	Identification models to lead to examples (NASA sulfur model)	Using cruise ships and instruments (car ferry towing instruments) acoustics; sampling water; image shadow image analysis; microwave radar on bow of ship to measure surface roughness; small scale of hyperspectral imaging; environmental tracers; miniaturized exploration / sampling techniques; fibre optics & Subs; ROV's; AUV's; dynamic positioning systems	WHOI, Harbor Branch; National Geographic
285	Currents & Water Masses	Mesoscale eddies - frequencies & importance; current flow patterns, eddies, mixing process, impact on bio, frequency & importance to ecosystems productivity, chem props	Current flow patterns; eddies; mixing process; impact on bio; frequency & importance to ecosystems productivity; chem props	Lake Superior; other Great Lakes; Yellowstone Lake	Standard Package; current meters; satellites; ADCP moorings; instrumented moorings; drift buoys; ADCPs; instrument arrays; acoustic imaging; sediment traps	Standard Partners, University of Toronto, Oregon State University, Scripps, WHOI
291	Ecosystem - Karst / Ring Depressions	Karst features in Lake Huron (sinkholes)	Spatial coverage; depth; dimensions; biology; chemistry; local flow pattern	Central Lake Huron	Standard Package; miniaturized exploration / sampling techniques; fibre optics & Subs; ROV's; AUV's; dynamic positioning systems; mass spectrometer	Standard Partners
292	Ecosystem - Karst / Ring Depressions	Ring depressions (400-500 m across; 20-30m deep)	How they formed; influence on distribution of benthic communities; sediments; contaminants; local flow patterns; why not in other lakes	Lake Superior	Standard Package; seismic reflection profiling; ROVs; sediment coring; subs	Standard Partners

Great Lakes Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
267	Ecosystem - Lakes	Lake Biodiversity	Bio / geo / chemical processes; origin of lakes; origin of species (evolutionary processes); community structures & compositions; species diversity - looking for new species; (3 african great lakes); rapid assessment survey; collection of long term sediment cores; geo-thermal vents systems; describe landscape census; looking for midwater scatters; multibeam survey; physical ocean sampling; natural history survey	Bia Kal Lake; African Rift Lakes; Lake Nicuragua; Great Bear; Great Slave Lake; Titikacica Lake; Yellowstone	Standard Package; ROVs / AUV / SCUBA / submersibles / hyperspectral remote sensors; in-situ sensor (long term); small vessel for estuaries; digital imagery; high frequency mid-level acoustic census	USGS; Country of Lake; Smithsonian; United Nations Environment Programme (UNEP); developing nations organizations; DOI, USGS; museums
277	Ecosystem - Lakes	Recharge of the all component parts lake systems	Use of streams for spawning; ecosystems approach to water quality; examine revival of species; pollutants	Test cases in Southeast Wisconsin; collaborative efforts with Canada & other international entities	Standard Package; miniaturized exploration / sampling techniques; fiber optics & subs; ROV's; AUV's; dynamic positioning systems; modeling technologies; maintenance of USGS gauge stations; broad scale monitoring	WHOI, Harbor Branch; National Geographic
290	Ecosystem - Seamounts / Ridges	North/south ridges in Lake Superior	Origin controversy; distribution of sediment & benthic communities; distribution of fish; influence of bottom currents	Lake Superior (Eastern half); Northern Lake Michigan; Eastern Lake Huron; Bering Sea	Standard Package; mapping; ROVs; subs; AUVs; sampling; moorings (ADCP)	Standard Partners

Great Lakes Workshop Results

ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
270	Episodic Events	integrating in discoveries with accountability need, basic research with applied science; event driven storms, surface and benthic storms; distribution of nutrients, biomass & current influences	Distribution of nutrients; biomass & current influences	Costal harbor estuaries	Moorings (long term); high frequency surface radar (CODAR); ADCP's; development of ecological observatories with (beyond normal sensors); new engineering - adaptive sampling instruments	Standard Partners
278	Extreme Environments - Sea Ice	Charactering ecosystems and other systems	Ice dynamics surveys sampling; systematic surveys; four dimension; hydrothermal systems; long term sediment records; rates of change; seasonal ice covered areas	Deep basin to shallow water volumes; winter in Great Lakes	molecular systematics genetics (method to measure diversity); environmental tracers; miniaturized exploration / sampling techniques; fiber optics & subs; ROV's; AUV's; dynamic positioning systems	WHOI, Harbor Branch; National Geographic
287	Extreme Environments - Vents, Seeps & Volcanoes	High resolution spatial & temporal zooplankton measurement over space & time, classification	High resolution zooplankton measurement over space & time; classification	Compare Lake Superior and southern Lake Michigan; 10 largest lakes in the world; Yellowstone Lake	Bigger faster vessels (stationed in Lake Superior); optical plankton counter; towed vehicles; AUVs w/ zooplankton counter; in-situ genetic tech; video image classification tech	Standard Partners
296	Extreme Environments - Vents, Seeps & Volcanoes	Hydrothermal features in lake systems	Chemistry; microbiology; nutrient dynamics;	Crater Lake; Yellowstone Park lakes; African Lakes e.g. Tanganyika; Baikal	Miniaturized exploration / sampling techniques; fiber optics & subs; ROV's; AUV's; dynamic positioning systems	Standard Partners
298	Extreme Environments - Vents, Seeps & Volcanoes	Seeps/ non-oxygen environments - endemic species, evolution in isolation, inter-lake comparisons, genetics in large time scales	Endemic species; evolution in isolation; inter-lake comparisons; genetics in large time scales	North shore of Lake Superior; bays; nearshore; upper peninsula Superior; Ashland Port urban environment	Standard package	Standard Partners

Great Lakes Workshop Results

ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
273	High Resolution Bathymetry	High resolution mapping of great lakes - survey of bottom of great lakes - shallow water mapping; extension of coastal estuaries & wetlands; understanding substrates to particle size; near-shore fossil coral reefs	Surveys; mapping; multibeam	Lake Superior; Lake Michigan; all the lakes; Yellowstone Lake (done this year); Crater Lake; African Lakes and other large Lakes; Mid-Lake Reefs; Mid-Lake ridge through Lake Huron; Lake Champlain	Standard Package; use of UNOLS w/multibeam; sub-bottom profiling; using side scanning sonar; seismic survey; hyperspectral imaging from aircraft; laser line scan; acoustic mapping; magnetometer; sub-bottom profiler; ROVs/subs	National Oceanographic Service; USACE; USGS; energy industry; museums
289	High Resolution Bathymetry	Mapping	Mapping; multibeam	Lake Superior; Lake Michigan; all the lakes; Yellowstone Lake (done this year); Crater Lake; African Lakes	Standard Package; Acoustic mapping; magnetometer; sub-bottom profiler; ROVs/subs	Standard Partners
269	Marine Organisms	Populations in flux; biological transitions zones	Linkages of rivers estuaries and basin; use of streams for spawning; ecosystems approach to water quality; examine revival of species; pollutants; identify organisms transitions zones; zebra mussel migrations; mapping of systems; transportation of organic and inorganic; identify organisms transitions zones; zebra mussel migrations; mapping of systems	Green Can Reef; Coastal areas; sea grasses; mangroves; Florida Bay	Time lapse; acoustic imaging of sediment layers; microscopic level	Standard Partners
284	Marine Organisms	Abyssal fish (> 50m)	Life history; impact of invasive species; spawning (where & how especially in winter season); character displacement behavior	Upper Great Lakes; Superior; Huron; Michigan; eastern basin of Lake Erie	Standard Package; ROVs; AUVs; time lapse camera systems planted on bottom in strategic locations; subs; acoustic scanner; long term video observation platform / time lapse cameras	Standard Partners, SIO; industry (esp. finances - power plants, fishing, fishing support); boating industry; Sea Grant Extension (outreach & funding); Jason Project

Great Lakes Workshop Results

ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
295	Marine Organisms	How animals use vision & light to orient themselves in the water	Visible communication	Deep water; shallows; freshwater vs. saltwater	Standard Package; photon cameras	Standard Partners
297	Marine Organisms	Evolutionary biology; endemic species, evolution in isolation, inter-lake comparisons, genetics in large time scales	Endemic species; evolution in isolation; inter-lake comparisons; genetics in large time scales	Lake Victoria; Lake Malawi; other African lakes; Lake Baikal; compare w/ Great Lakes	Genetic tech; microbiology techniques; capture techniques	Standard Partners
268	Pelagic Environment	Pelagic habitat - ecosystem behavior's; both physical systems and benthic landscape; identifying boundary fluxes; identify microscale of physical / chemical processes; eddies & fronts; data mining & modeling	Intensify systems in time and space scale; global loss of biological diversity (loss of taxonomy and systematics skills) human technologies to resurrect core competence and knowledge; people & technological interface needed to continue the skills (greater diversity in program - mainly older / white males)	Biological hot-spots (Benthic & Pelagic Water Columns)	Sensors & Critter Cams - PSATS; Zoo Cam's; Fish Cams; buoy networks; upward looking devices to monitor water column; dockable AUV's; recycle oil rigs on mid-lake ridge; long term observatory	NWS; NESDIS; energy industry; Coast Guard, Navy; USACE; NSF, DOI, USGS; insurance industry
276	Pelagic Environment	Constant monitoring of pelagic community - buoy networks, or an upward looking devices to monitor water column	Buoy networks; or an upward looking devices to monitor water column	Lake Michigan for comparison of Older transects	Miniaturized exploration / sampling techniques; fiber optics & subs; ROV's; AUV's; dynamic positioning; more adaptive sensors following events	Standard Partners; WHOI, Harbor Branch; National Geographic
280	Pelagic Environment	Life in one cubic meter of water; seasonal change, species change, ID & characterize, transition rates, feeding rates, all of the rates	Seasonal change; species change; ID & characterize; transition rates; feeding rates; all of the rates	Contrast temperate vs. tropical; nearshore fresh vs. salt; contrast different parameters	Holography; acoustic doppler; dns; fluid simulation; IR laser scan (need low Reynolds# on machine); micro-chemical sensors; AUVs; ROVs; subs; sampling; neutrally buoyant chemostats	Standard Partners; Johns Hopkins University; University of Rhode Island

Great Lakes Region Exploration Targets of Interest

1. Africa's Great Rift Lakes - Malawi and Tanganyika (not on chart)
2. Crater Lake, Oregon (not on chart)
3. Death's Door Passage
4. East African Rift Lakes - Lakes Edward, George, and Victoria (not on chart)
5. Great Bear Lake (not on chart)
6. Great Slave Lake (not on chart)
7. Green Bay
8. Green Can Reef
9. Keweenaw Peninsula
10. Lake Baykal (not on chart)
11. Lake Erie
12. Lake Huron
13. Lake Michigan
14. Lake Nicaragua (not on chart)
15. Lake Ontario
16. Lake Superior
17. Saginaw Bay
18. Straits of Mackinac
19. Titikacca Lake (not on chart)
20. Yellowstone Lake (not on chart)

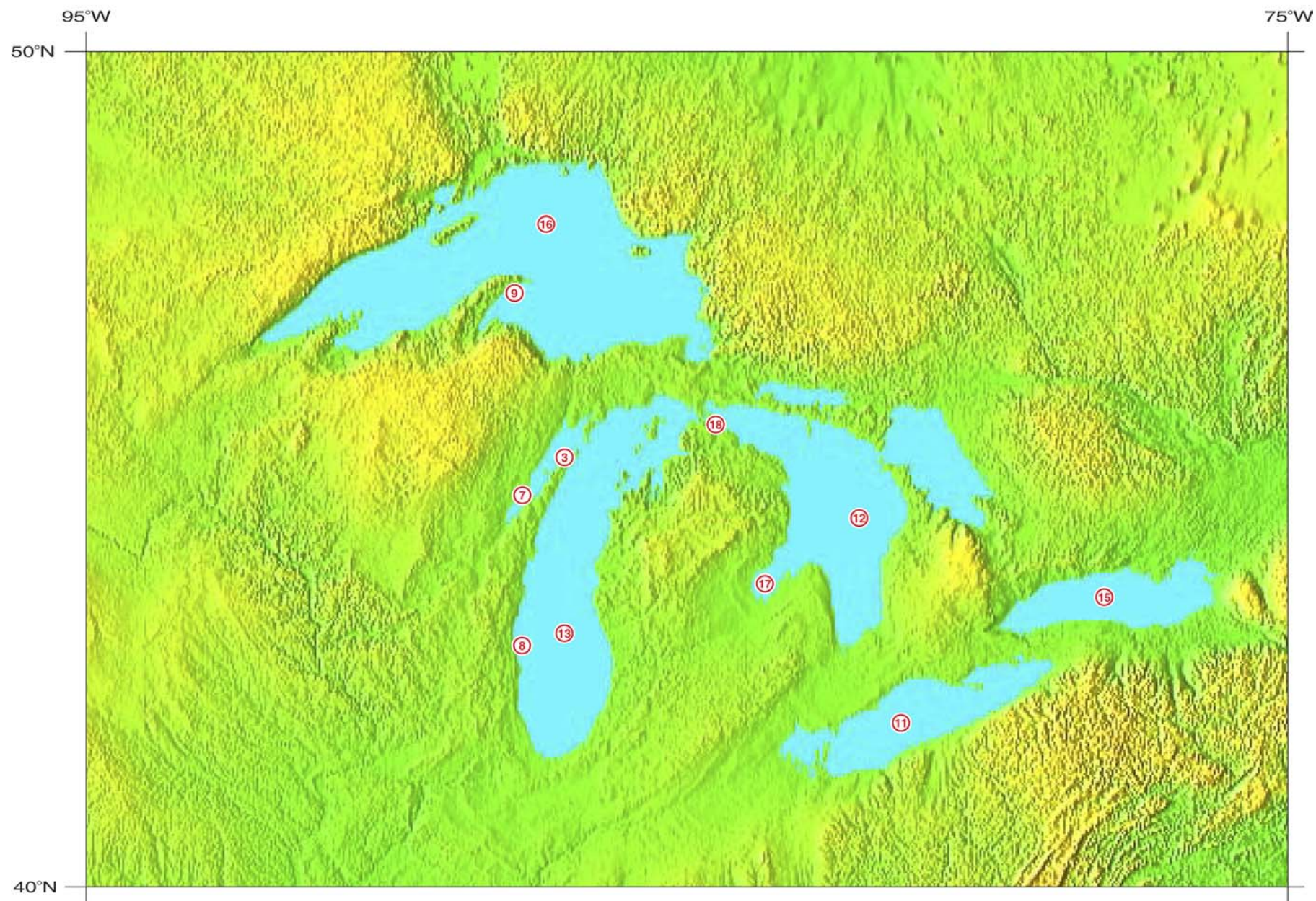


Figure 3-9. Great Lakes Region Exploration Targets of Interest

3.4.8 South Atlantic Region

Participants in the South Atlantic region workshop emphasized interest areas related to the identification and location of deep corals and their interaction with ocean currents and fish habitats. The group discussed the expansion of fisheries exploration including the mapping and inventory of fisheries in the Gulf Stream. Other important geographic targets identified as needing further exploration included wide areas of unknown underwater features near the boundaries of the continental shelf, including the canyons of the Bahamas Banks and South Atlantic Bight.

The participants had significant interest in documenting wrecks and other cultural resources with the intent of blending archeological missions with other exploration activities.

An improved process for managing exploration data was a topic of significant discussion, particularly related to the life cycle processes for collecting, storing, and accessing these data. Participants shared ideas for workable processes that could satisfy the outreach needs of the OE program while recognizing the needs of the principal investigator for processing, analyzing, and publishing results of collected data.

Results of the South Atlantic region workshop are provided in Table 3-10. Exploration targets of interest nominated by participants are illustrated in Figure 3-10.

Table 3-10. South Atlantic Region Workshop Results

South Atlantic Workshop	
<p>Standard Package: Class I/II Vessel with acoustic mapping (multibeam; sidescan); Dive capability (ROV/AUV/Subs) with imagery/video and sampling equip; Precise positioning equipment; Real-time information transfer (video; email; web); GIS; Bottom samplers; Grab samplers; Water column sampling - rosettes; CTD; Plankton sampling; Fish sampling -</p> <p>Standard Package 1: Class I/II Vessel with acoustic mapping; Dive capability (ROV/AUV/ Submersible) with imagery/video and sampling equipment; Precise positioning system; Magnetometer; Sidescan; Sub-Bottom profiler; Flow thru system; Standard Package 2: NR1 submarine-like vessel; Standard Package 3: Mobile habitats</p>	<p>Standard Partners: Universities; USGS; State Departments of Natural Resources; NMFS; NOAA sanctuaries; Sea Grant; NOS; MMS; WHOI; HBOI; NASA; NSF; ONR; Space Grant; COSEE; OE; Army Corps of Engineers; Aquariums; Museums; Archaeologists; National Park Service; Navy; States; State Historic Preservation Office (SHIPO); Industry; Media; Educators; NESDIS</p>

South Atlantic Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
305	Archeology	Submerged cultural resources	Document status of wrecks; recently uncovered by storms; etc. using systematic surveys or target submersible historical shipping lanes; sites know in historical records; sub-bottom formation identification of targets; consistent survey of coastline areas out to EEZ	Hatteras to Keys; USVI	Standard Package; AUVs; photo mosaics; video imagery; multibeam; sidescan sonar; magnetometer; airborne LIDAR; integrating sensing collection systems and positioning system; real-time video linked to shore	Standard Partners
325	Corals - Deep water	Deep sea coral mounts (oculina and lophilia)	Map associated fauna; area; extent; size of mounds; new species	400-600m depths; Blake Plateau - Cape Fear to Bahamas	Subs; sonar; sampling technology	Standard Partners
306	Currents & Water Masses	Mapping currents and eddies and their connection to vertical and horizontal components	ID circulation; temperature discontinuities; current velocities; pH levels	Gulf Stream to inlets	Satellites for SST; drifters; buoys; ADCP; AUVs	Standard Partners

South Atlantic Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
324	Currents & Water Masses	Exploring Gulf Stream and Florida Gulf Current	ID; characterize; map; habitat assessment/map; nutrient cycling; life history/reproductive biology/evolution of life history strategies of fishes; moored current meters at multiple depths; sediment traps; release drifters regularly from position on the sea floor and use satellites to track them; release drifters regularly from position on the sea floor and use satellites to track them	Blake Plateau - deep; under Gulf Stream/Florida Current; lots of new species found there; difficult access; Portales Terrace - lots of fish habitat; unexplored regions; other significant deep regions in Florida Straits; Miami Terrace;	Standard package; high current subs; ROV's; side scan; multibeam; seismic tech; ADCP; moored instruments; sediment traps; neutrally buoyant sediment traps; New technology: develop baited fishing gear - automatic release fishing gear such as magnesium links that dissolve - needs to get to bottom quickly and do it's job of fishing or photographing and then pops up to the surface when done; AVHRR (SST); SeaWiFS (ocean color); satellites	Standard Partners; NWS (especially moored); recreation community; fishing; boat industry
319	Ecosystem - Banks & Basins	Bahama Banks	Explore mechanisms behind whiting events; sea level studies; geology; karst studies; low standing reefs; archeology - shipwrecks; reef studies; coral bleaching; carbonate production; reef sampling/coring for sea level and paleoclimate studies; highly migratory species; fisheries oceanography; many habitats to observe different regions; using ships; satellites; satellite based; remote sensing; satellite telemetry; critter behavior; sea level data; sediment traps; water column sampling	Tongue of the ocean (TOTO); Florida Straits; Exumas (island chain)	Standard Package; coring; sediment traps; water column sampling; 3-D seismic; LIDAR; cameras; ABLOS (a boat load of stuff); SCUBA; Aquarius and other habitats; remote sensing	Standard Partners; CMRC Caribbean Marine Research Center (CMRC) at Lee Stocking Island; San Salvador; education partners; Bahamas government
316	Ecosystem - Canyons	Explore canyons and holes	Map; characterize; ID; turbidity transport; mineral exploration; gas and groundwater seeps	Hatteras; Carolina sea trough; Desoto canyon; the Point off Cape Hatteras; Red Snapper Sink Hole - off Jacksonville	Standard Package; subs; tech diving; sonar; seismic; sidescan; multibeam bathymetry	Standard Partners
308	Ecosystem - Extreme Environments - Vents, Seeps, & Volcanoes	Map dead and living muscle & clam communities associated with seeps	Compare with subsurface; ID survey	Blake Ridge	multibeam; coring; sub; gas hydrate sensors	Standard Partners

South Atlantic Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
341	Ecosystem - Extreme Environments - Vents, Seeps, & Volcanoes	Heat flow measurements	Heat flow measurements on the ocean floor extending hundreds of kilometers normal to, and on either side of, rapidly spreading ridge axes (or hot spots)	Ocean wide near spreading ridge axes or hot spots		
303	Ecosystem - General	Primary & secondary fish production; understanding geochemical processes	Collect water column; physical data; use satellite imagery; collection of mid/bottom biologics; net and bottom sampling; connecting bio/chem/geo technologies and processes; eddy processes; ID drivers of production; Lagrangian perspective; food web	Charleston Gyre	CTD; automated sensors; automated ship - compiling/integrating; management of data; real-time continuous data collection; "conducting cable"; collecting satellite data - SST; SeaWiFS; ARGOS; transmit broadband data; multidisciplinary ship time; drifters	Standard Partners
304	Ecosystem - Shorelines to Ledges	Connectivity of habitats on shelf and edge of shelf; trophodynamic study	ID connected habitats; extent of spawning areas; inventory of habitats and communities; connection between reefs; sample; determine source; track history of fish; follow biologics to determine behavior; tagging studies; molecular data analysis	Marine Protected Areas; Hatteras to Texas	Spectral technologies; PSATS/conventional tagging; chemical tools	Standard Partners
315	Ecosystem - Shorelines to Ledges	Inner shelf	Surficial geology; bathymetry; sediment distribution; biota; habitat distribution; potential fish habitats; groundwater discharge; relationships between biology and geology; physical oceanography - water mass characteristics; invasive species; harmful algal blooms	Grays Reef; Georgia coast; Florida coast; SE NC coast least studied; SC coast	Standard Package	Standard Partners
318	Ecosystem - Shorelines to Ledges	The Point	Extend baseline info; why is it so productive?; map	Just off Cape Hatteras	Subs; mapping; sediment traps	Standard Partners

South Atlantic Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
302	Ecosystem - Slopes	Shelf to slope transition area; complex habitats - reefs (outer shelf), deep coral banks, canyons	Survey bottom; physical sampling of water column dynamics; biological survey; sampling structural data; describing wreck structure; wood samples from wrecks; corrosion analysis; sampling substrates; subsurface geology; site stabilization; covering and uncovering of wrecks; observe new species; species interactions/behavior; habitat utilization; network of sensors; multidiscipline surveys; fisheries; ID community structures; (Assume already have good bathymetric data); characterize content of entire water column (*planned comprehensive surveys); *staged multiyear plan ; generate time line	Hatteras to Texas	Standard Package; magnetometer; sidescan; sub-bottom profiler; flow thru system; HDTV; subs in strong currents; remote sensing of Gulf Stream; HDTV cameras; photo mosaic; multiple cameras/sensors - fiber optic technology	Standard Partners
317	Ecosystem - Slopes	Explore shelf break - upper slope	Mapping; characterize; ID; intercomparisons; moored arrays; satellite; airborne; LIDAR; drifters; shelf edge; reefs; hard bottoms; paleoshorelines; spawning locations; sand resources; sediment traps; broad based exploration survey; expansion of MARMAP monitoring (fisheries monitoring program funded by NMFS to SC); habitat based observation; turbidity transport; mineral exploration; gas and groundwater seeps; dedicated estuarine coastal vessel for education and training of next generation of oceanographers to establish monitoring program of data and sample collection - potentially re-outfit Ferrell for this purpose	S. Atlantic Bight; oculina banks; compare among . . . Cape Canaveral; Hatteras Slope; S.Carolina-Georgia border	Standard Package; habitat; SCUBA; moored (similar to LEO); ROV observation satellite; airborne; sediment traps; coring; Mochness; seismic; subs; tech diving; ROV's; AUV's; moored arrays; multibeam; sidescan; seismic; chirp sonar	Standard Partners; oil industry; ocean tech companies; military
314	Geology & Geomorphology	Mapping paleoshorelines and relict reefs (tend to be fish habitats)	Map; ID; characterize; develop baselines for geology; biology; water quality	Reefs; W. Florida shelf; Keys; shorelines everywhere - shelf edge; Bahamas	Standard Package; bottom sampling; multibeam; subs; side scan; seismic tech; chirp sonar	Standard Partners

South Atlantic Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
321	Marine Conservation	South Atlantic Fishery Management Council (SAFMC)	Map; ID; characterize; develop baselines for geology; biology; water quality; determining potential recreational interests; oceanographic parameters; putting areas on map for proposed marine reserve areas - politically driven; need to explore these regions to ID whether these are appropriate reserve areas biologically; ecologically; etc.	SAFMC has maps; deeper ones off N. and S. Carolina; Georgia; Florida; Gulf of Mexico	Multi-beam; AUV; ROV; subs; tech diving; permanently mounted instrument arrays	Standard Partners
322	Marine Conservation	Recruitment and spillover mechanisms in MPA networks	Oceanographic parameters/processes; info on spawning; eggs; larvae spillover and transport mechanisms; behavior of early life history stages that effect recruitment	Region-wide; spawning locations; paleoshoreline ridges such as Pulley Ridge; Dry Tortugas; Marine Protected Area's and adjacent areas; Charleston Bump	Nanotechnology; AUV (WHOI); multibeam; subs; satellite tags on spawning fish; drifters; moored arrays	Standard Partners
323	Marine Conservation	Oculina Banks	What is effect of closure?; 10 yr limit on no fishing; ID; characterize recruitment and spillover mechanisms; artificial reef impact; comparison with existing baseline studies	S. Atlantic Bight	Subs; ROV's; tech diving; multibeam; moored arrays; sidescan sonar; chirp	Standard Partners
330	Marine Microorganisms	Chemosynthetic communities	Subsurface - down several km; oil seeps and vent communities; inventory and characterize; isolated ridge system; new biota; larger geographic context	Blake Ridge; Gulf of Mexico	Standard Package; multibeam; geophysical techniques; sampling techniques; satellite imaging; towed vehicles; subs; AUV's; look at new technologies	Standard Partners
320	Marine Organisms	Expanding fisheries (exploitation of new species)	Establish fishery dependent sampling & fishery independent sampling baseline information such as growth rates; reproduction; etc.; getting samples from landings reproduction; etc.; conducting independent surveys to get better estimates of abundance; life history; reproduction; growth rates; all base-line information; education effort	Opportunistic; region-wide	Standard Package; baited traps; trawling; standard package; Mochness	Standard partners; SAFMC; industry associations such as Coastal Conservation Association and other sport fishing clubs; commercial fishing associations; Reef Environmental Education Foundation (REEF); Professional Association of Diving Instructors (PADI); NMFS

South Atlantic Workshop Results						
ID	Category	Information Need/Gap	What	Where	Enabling Technologies	Partners
327	Marine Organisms	Seasonality of upwelling and associated spawning and larval distribution	Map locations of upwelling and gyres; measure productivity; sample plankton; measure vertical flux to sea floor; physical/chemical water column characteristics	N. of Cape Canaveral; N. of Charleston Bump - semi-permanent gyres; also smaller ones but don't know much about them - unknown areas	Data buoys; moored arrays; satellite; plankton sampling; sediment traps; standard oceanographic sampling - CTD; ADCP; fluorometry	Standard Partners
328	Ocean Resources - Bioprospecting	Bioprospecting	Charleston Bump (mg); Blake Plateau (gas hydrates; sand); inner shelf; collect samples of marine organisms; water samples; sediment samples; collect DNA from marine organisms	Any of regions/projects stated above - opportunistic	Standard Package; Rock dredging; sand collecting tech; standard package; seismic; sub-bottom profilers; bioprospecting tools; subs; ROV's; low tech shipboard sampling such as trawls and dredges; genomic tech; molecular tech	Standard partners; biotech; Centers for Disease Control (CDC); local governments
307	Ocean Resources - Energy & Minerals	Discovery of deep sea minerals, deep sea biota	Surveys - subsurface; ocean drilling programs	Blake Plateau	Standard Package	Standard Partners
329	Ocean Resources - Energy & Minerals	Mineral prospecting	Charleston Bump (mg); Blake Plateau (gas hydrates; sand); inner shelf; manganese nodules; phosphorites; gas hydrates; sand resources for beach nourishment; heavy metals	Near-shore regions; Region-wide; off Hatteras; Charleston Bump; Blake Plateau; Blake Ridge	Standard Package; multibeam; chirp sonar; seismic; ROV's; subs; bottom sampling; corers; grabs; dredges; side scan; rock dredging; sand collecting tech; seismic; sub-bottom profilers; bioprospecting tools	Standard partners; biotech; CDC; local governments
326	Pelagic Environment	Shelf-wide water column oceanographic studies (physical, biological, chemical)	What causes harmful algal blooms; circulation; nutrient distributions; nutrient flux; mixing; recruitment dynamics; jellyfish (sea nettles); water column sampling; time-series monitoring and collecting water samples; monitor as event occurs	Region-wide; N. Carolina; Onslow Bay	Standard Package; moored arrays; upgrading and expanding the SABSOON network; ADCP; permanently moored data buoys; drifting sediment traps (vertex style); satellite imagery; drifters; general oceanographic sampling - CTD; ADP; water sampling	Standard Partners

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Atlantic South Region Exploration Targets of Interest

1. Bermuda
2. Blake Plateau
3. Blake Ridge
4. Cape Canaveral
5. Cape Hatteras
6. Charleston Bump
7. Charleston Gyre
8. Grays Reef
9. Hatteras Slope
10. Onslow Bay
11. Red Snapper Sink
12. South Atlantic Bight

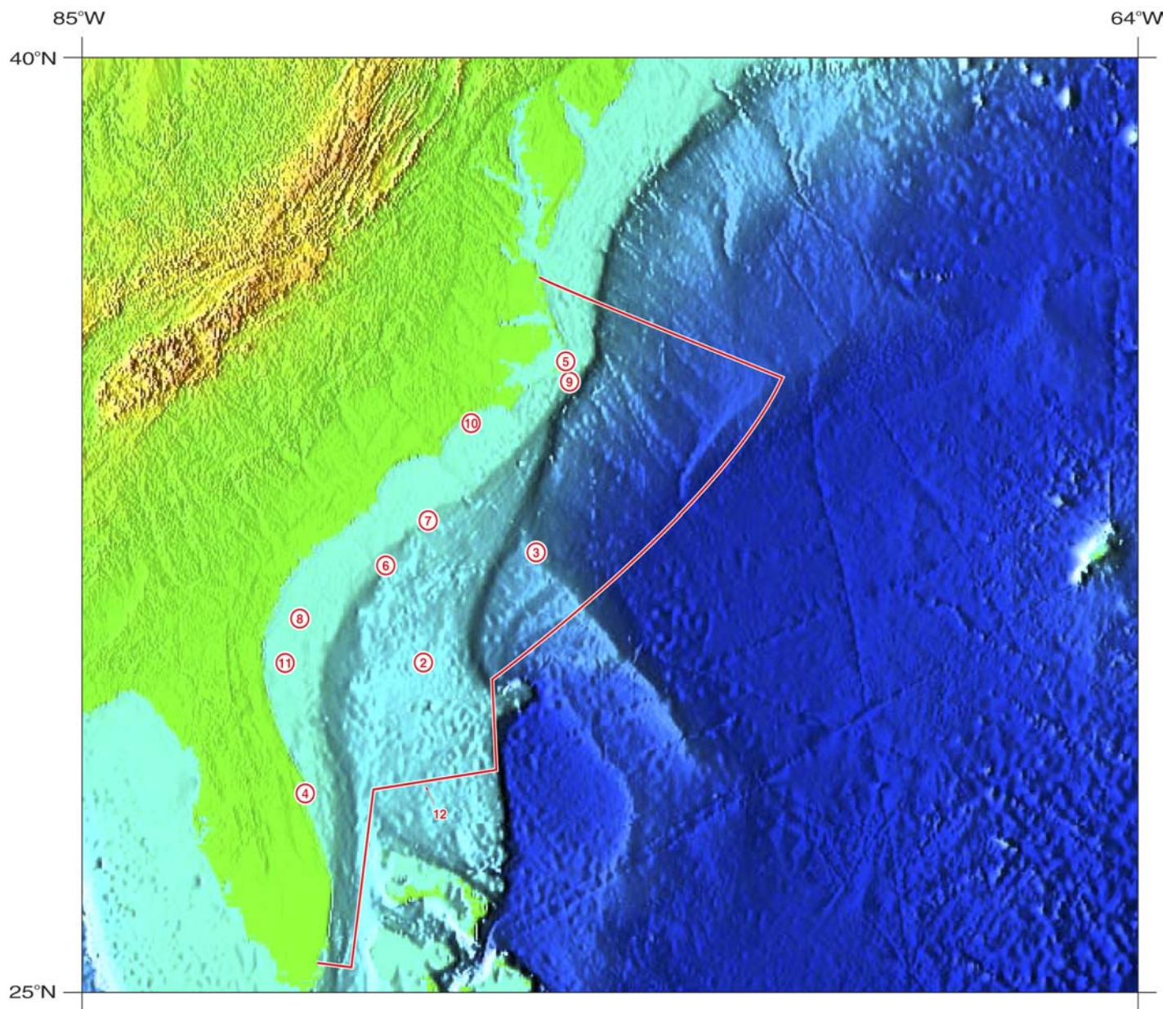


Figure 3-10. South Atlantic Region Exploration Targets of Interest

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4 Conclusions

Several initial conclusions may be made based on an initial analysis of the data collected at the regional exploration workshops. This section compares the workshop data to the national vision contained within the *Frontier Report*, discusses the probable impact of these data on capital assets such as research vessels and supporting equipment, and presents related issues arising from the workshop proceedings.

4.1 Synergy with *Frontier Report*

The road map provided by the *Frontier Report* presents four national exploration objectives⁷, each with a subset of elements describing the specific challenges within the stated objectives. As detailed in Table 2-2, these objectives and their elements provided the foundation for the workshop process and offered general guidance to workshop participants on areas of exploration emphasis. Since the two exploration objectives related to technology development and reaching out in new ways to stakeholders were presented as crosscutting themes during the workshops, each of the exploration needs categories from the workshops listed in Section 3.1 include components from both of these objectives. The emphasis of elements comprised within the two objectives related to mapping and dynamics are more specific in their application to ocean exploration. The relationship between these elements and the exploration needs categories identified by the workshop participants is provided in Table 4-1. Several conclusions may be reached using this table in conjunction with detailed information on the exploration needs categories presented in Section 3.

- The national emphasis on biological, geological, chemical, and physical interactions and exploration of the connections between living and nonliving systems is nearly ubiquitous among the categories of exploration needs. This result is consistent with the desirable characteristic stated in the *Frontier Report* that each facet of exploration should be multidisciplinary by necessity.⁸ It also supports a commonly held view that involvement of subject matter experts across multiple scientific disciplines is fundamental to successful ocean exploration. Their involvement is necessary to ensure new, discipline-specific discoveries are recognized from within diverse ocean exploration data.

Table 4-1. Relationship Between Elements of Selected Frontier Report Objectives and Workshop Exploration Needs Categories

Workshop Exploration Needs Category	Elements of Selected <i>Frontier Report</i> Objectives								
	Archeological Sites	Resources	New Species	Ecosystems	Ocean's Interior	Ocean Floor	Ocean Properties	Sea Surface	Bio/Geo/Chem & Physical Interaction
Archeology	X					X			
Artificial Habitats	X			X					X
Benthic Environment		X	X	X		X			X
Boundary Fluxes - Air/Sea					X		X	X	X
Boundary Fluxes – Basins					X	X	X		X
Corals - Deep Water		X	X	X					X
Corals - Shallow Water		X	X	X					X
Currents & Water Masses					X		X	X	X
Ecosystem – General		X	X	X					X
Ecosystem - Abrupt Topography		X	X	X		X			X
Ecosystem - Banks & Basins		X	X	X		X			X
Ecosystem - Extreme Environments – Sea Ice		X	X	X					X
Ecosystem - Extreme Environments - Vents, Seeps & Volcanoes		X	X	X		X			X
Ecosystem – Caves		X	X	X					X
Ecosystem – Lakes		X	X	X					X
Ecosystem - Shoreline to Ledges		X	X	X		X			X
Ecosystem – Slopes		X	X	X		X			X
Episodic Events					X		X	X	X
Geology & Geomorphology		X		X	X	X		X	X
High Resolution Bathymetry					X	X			
Human Impacts		X					X	X	X
Marine Conservation	X	X	X	X		X			X
Marine Microorganisms		X	X	X				X	X
Marine Organisms		X	X	X					X
Ocean Resources – Bioprospecting		X	X	X		X			X
Ocean Resources - Energy & Minerals		X			X	X			X
Pelagic Environment		X	X	X	X				X
Sound in the Ocean		X		X	X	X	X		

- The *Frontier Report* emphasizes mapping as a means of characterizing ocean areas not previously observed and conveying the results of discovery. While there is a specific needs category for high-resolution bathymetry, the mapping needs identified during the workshops are encompassed within almost every single needs category. The mapping aspect of ocean exploration is viewed as a fundamental and mandatory component of the process of documenting discoveries.
- The importance in the *Frontier Report* on the search for knowledge related to new communities of organisms in ecosystems that display novel relationships with their environments and provide sources of new species and oceanographic resources was a major interest of workshop participants. The categories related to ecosystems have the greatest impact on requirements—both in volume and technology development—related to the mapping of previously unobserved regions.
- The element associated with the identity, location, and abundance of living and nonliving resources was a priority among the ocean explorers represented at the workshops. Although the *Frontier Report* identifies the U.S. EEZ and continental margins as geographic foci for application of this element, workshop participants were not constrained by this paradigm and identified many regions of interest outside these areas.
- Elements in the *Frontier Report* related to general physical oceanography and dynamic features of the physical ocean—particularly those related to surface observations—were not emphasized by workshop participants to the same level as other exploration needs. One possible explanation is the extensive ongoing investment in research activities related to global climate change and the hydrological cycle, activities that are rooted in hypothesis-based research and provide a steady stream of serendipitous discoveries. Another explanation is the perception among participants that remote sensing of the sea surface was not a goal unto itself but represented a potential data source that could be combined with a multidisciplinary mix of related ocean exploration data. It is likely that there are simply fewer opportunities for new discoveries where existing operational sensors provide routine observations, de-emphasizing the associated need for attention and investment by the OE program.
- Although the needs related to marine archeology and the preservation of America's maritime heritage were neatly confined to specific needs categories, this *Frontier Report* element was a consistently recurring need at each of the regional workshops.
- While spatial and temporal variability of the ocean and its inhabitants are both addressed in the *Frontier Report*, the workshop results accentuate spatially related exploration needs over time variant needs. Given the importance of mapping—an inherently spatial endeavor—for documenting the outcome of exploration activities, these results are not unexpected. Also, one could argue that subsequent “visits” to an area of interest to establish a temporal record of variability, following its initial revelation through exploration, would include a cadre of scientists armed with hypotheses for explaining anticipated changes and could focus on related scientific research rather than exploration.

In addition to conclusions drawn from references to Table 4-1, several other relationships between the vision contained within the *Frontier Report* and the results of the regional workshops are evident upon review of the data and are listed following this paragraph. One area that was not emphasized by workshop participants was the structure of a national exploration program and related programmatic guidance. There was an assumption among the participants that NOAA and OE would retain its current national leadership role in ocean exploration and would facilitate execution of the OE program in partnership with an appropriate suite of public and private stakeholders. Several participants requested a more formal definition of the scope of the OE program and criteria for the selection and peer review of projects so that they might tailor their proposals accordingly.

- Items within the *Frontier Report* objectives that were emphasized across all regional workshops include the need for state-of-the-art technology in supporting tools, coordinated education and outreach as a mandatory component of all exploration activities, a data management capability for exploration data, and creative collaboration with a broad population of exploration stakeholders. Workshop participants usually addressed these needs as broad, crosscutting themes critical to the success of their conceptual exploration approaches rather than unique exploration needs categories analogous to those in Table 3.1. Capital asset needs related to research vessel capacity and technologies are discussed in the following section.
- Given the fact that the eight workshops were regionally focused, associated exploration needs were naturally focused within the general geographic boundaries of each region. The national obligation to concentrate initial exploration efforts in the U.S. EEZ and continental margins claimed in the *Frontier Report* is mirrored in the workshop data. Despite the regional focus, participants were willing to nominate other geographic areas of interest, such as the Arctic and inland seas. One priority area from the *Frontier Report* that was not considered a priority by the workshop participants is the region of the Southern Ocean. Several participants explained this lack of emphasis on an assumption that exploration activities in the extreme southern hemisphere would be cost prohibitive unless the OE program had access to a dedicated exploration platform. The distribution of geographic areas of interest is illustrated in the charts contained in Section 3.4.
- Workshop participants through their nomination of potential partners from industry, government, academia, nongovernmental organizations, and the media validated the weight in the *Frontier Report* on ocean exploration partnerships. There was also recognition that NOAA and OE were strongly supportive of the spirit of this vision as evidenced by their considerable list of collaborators constructed during the initial year of the OE program. Participants validated the OE program's commitment of resources to three of the four capital investment areas listed in the *Frontier Report*:

interdisciplinary voyages of discovery in high-priority areas, data management and dissemination, and education and outreach. Participants generally agreed that the fourth investment area—platform, communication, navigation, and instrument development—would require an additional infusion of resources into the OE program in order to begin to satisfy national needs without sacrificing the viability of the program.

- Emphasis in the *Frontier Report* on realizing the potential of discoveries and protecting new discoveries was reflected in the exploration needs generated by workshop participants. While there was recognition of the commercial potential of selected discoveries and the need to protect related resources, participants did not address programmatic issues such as fast-track research initiatives and financial incentives for encouraging this commercial development. An additional interest item resulting from the workshops was the need for collaboration and incentives for industry to share unique data and information that would otherwise be unavailable to the government and the public due to their commercial value to the owner.

The combined results of the ocean exploration workshops generally reflect the four strategic objectives offered by the *Frontier Report* with emphasis on the actual conduct of exploration activities. The exploration needs and associated approaches for meeting those needs provide valuable implementation guidance for near-term execution of the OE program.

4.2 Capital Asset Needs

Impacts related to the employment of ocean exploration platforms and improved exploration technology were exposed as a byproduct of the approaches identified by workshop participants for satisfying ocean exploration needs. These impacts provided the opportunity for a qualitative assessment of the necessity for supporting platforms—particularly surface-based exploration vessels—to enable the OE program to address the needs summarized within this report.

4.2.1 Ship Capacity

An inspection of the regional workshop results in Section 3.4 reveals over 230 specific geographic interest sites and many broad-area interest regions identified by participants as desired candidates for exploration activities. While a majority of these areas are within the U.S. EEZ, there are many that are located outside these boundaries and a few at considerable distances from these waters. Section 3.4 also lists over 200 ocean exploration needs that either specifically refer to surface-based vessels as an enabling

technology (i.e., as part of a “standard package” of technologies) or imply a use of these vessels to deploy associated sensors and supporting systems. This combination of needs and locations represents many thousands of nautical miles of exploration vessels transiting and exploring these areas. Additionally, over four-dozen specific sites—and many other general regions—are identified as areas of archeological interest where an extended presence would be required to support characterization, artifact recovery, and preservation.

It is nearly impossible to quantifiably estimate the requirements for ship capacity to meet the exploration needs identified during the workshops due to the complex relationship between the geographic areas of interest and the multiple needs that apply at each location. A qualitative assessment of the requirements for ship capacity is possible using the first demonstration year of the OE program as a template for making assumptions about rates of area coverage, associated costs, leverage of partnership assets, and ship employment. During the 2001 field season, seven major expeditions employed nine ships and spent approximately 340 days at sea exploring 18 general geographic areas of interest. The activities ranged from the *Preserving the USS Monitor* archeological expedition that spanned a 140-day period at a static site and was principally supported by a Navy salvage vessel, to the *Islands in the Stream* expedition that occurred over a 110-day period and visited nine unique areas using three vessels operated by NOAA and by the private Harbor Branch Oceanographic Institution. If the *USS Monitor* expedition is considered separately given its unique archeology and artifact recovery missions, the remaining OE program field season provided or leveraged eight ships and visited 17 unique geographic areas while spending approximately 190 cumulative days at sea, a simple average of about 11 days of ship time for each non-archeological area of interest. Direct costs to the OE program for ship capacity to support its expeditions ranged from zero in the case of selected NOAA vessels—with operating and maintenance costs covered by NOAA—to a rate approaching \$1M for 30 days of access to the deployed, deep-diving capabilities offered by a Class I vessel and equipment suite analogous to the *R/V Atlantis* and the *Alvin* submersible operated by the Woods Hole Oceanographic Institution.

A simple extrapolation of ship capacity requirements to satisfy the subset of total exploration needs identified, including those related to marine archeology, leads to the conclusion that a number of days of ship time on the order of 10,000 would be required to conduct ocean exploration activities at the interest areas identified during the workshops. This estimate of required ship time is likely quite low due to the following reasons:

- Some of the general regions of interest are quite expansive and are guaranteed to include multiple sites where subsequent exploration activities will be desired
- Many of the sites of interest are geographically distant and are beyond the scope of the existing OE program (e.g., the Mid-Atlantic Ridge, Micronesia and the Pan-Pacific, etc.)
- The workshop participants represented only a subset of the total ocean exploration stakeholder community, thus the identified sites of interest are likely to expand as this broader stakeholder community becomes engaged in the program
- To achieve the multidisciplinary benefits desired by exploration stakeholders, extended time-on-station at many sites will be required
- National areas of interest identified in the *Frontier Report*, such as the expanse of the Southern Ocean, were not identified during the course of the workshops

Despite the fact that the estimated requirement for ship capacity is fairly conservative, it represents a demand for resources in excess of \$300M for time aboard non-NOAA vessels meeting the minimum “standard package” capabilities identified by the workshop participants. By comparison, initial OE program budget estimates in December 2001 for ship time during 2002 field season, with 85 days of projected NOAA ship time—75 days in partnership with the National Marine Sanctuaries aboard the *R/V McArthur* and 10 days on the *R/V Ron Brown*—and based on the current year \$14M total program budget, included approximately \$3.5M for an estimated 250 days of ship time supporting exploration activities. These figures do not include the leveraging of Navy assets supporting continuing artifact recovery at the *USS Monitor* site. Given the existing availability of government-owned vessels and the program’s funding level, the OE program would require about 90 years to complete a single expedition to each of the target areas of interest identified by workshop participants, assuming all geographically distant sites were accessible.

A specific recommendation contained within the *Frontier Report* is the completion of a multi-year voyage of discovery as a signature mission.⁹ Although not addressed in detail

by workshop participants as a specific need, it is evident that a vessel dedicated to this mission would be capable of satisfying many of the needs identified within this report and would be able to bring a large number of the distant sites of interest into range. From an operational perspective, a dedicated vessel could provide as many as 280 additional operational days at sea each year. Relative to program costs, such a vessel would free up considerable OE program funding for direct application against investigator proposals and technology development needs, expand the program's capacity to meet the requirements of the stakeholder community and those stated within the *Frontier Report*, and provide a large benefit/cost ratio for NOAA as funding formerly required to cover the costs of ship time aboard non-government vessels is redirected to OE program activities and participants. A dedicated vessel would provide a platform capable of supporting permanent integration of supporting technologies and a concurrent enhancement in capabilities. It would also facilitate the establishment of an extended partnership with a broadcast or film media group of national or international scope—one that is certain to seek continuity in the environment, equipment, and participants so that viewers have the opportunity to establish familiarity with the surroundings and virtual relationships with the explorers.

4.2.2 Technology Development

Participants in each of the eight regional workshops identified a broad range of technologies associated with companion approaches for satisfying ocean exploration needs. The candidate areas for technology development were nominated based on their potential to facilitate satisfaction of each need and were not examined in greater individual detail by the workshop participants due to the other time demands of the workshop process. Technologies identified by each region appear within the tables provided in Section 3 and have been summarized in this section by categorizing them and eliminating clearly duplicative technology needs. The results of this process are provided in Table 4-2. No attempt has been made to prioritize the technology areas listed in this table. Desired actions related to the technology areas identified by workshop participants are divided into three categories. Several of the identified technologies are candidates for multiple categories—for example, tailored AUVs for archeological assessment are appropriate in either the Platforms or Marine Archeology categories—but are listed only

once within the most representative category (in this case, Marine Archeology). The perceived target of potential future investments distinguishes the definitions of these categories:

- *New Development.* Investments are required to develop fundamentally new technologies that provide innovative ocean exploration capabilities to meet emerging needs
- *Improve Capability.* Investments are required to enhance the ability of emerging and existing technologies to meet evolving ocean exploration needs
- *Expand Capacity.* The required technologies exist; however, investments are needed to facilitate increased access by ocean explorers to these technologies

Table 4-2. Regional Workshop Technology Needs

Category	Desired Action	Technology
Communications	Improve Capability Expand Capacity	remote data link maritime communications services real-time information transfer broadband communications
Data Processing	New Development Improve Capability	conversion of molecular data to signals Automated Wrecks & Obstructions Information System (AWOIS) data processing and visualization tools digital ID tools digital process annotation fingerprinting technology Geographic Information Systems (GIS) intelligent agents processing/visualization tools visualization techniques
Genomics	New Development Improve Capability	genetic markers genomics on a chip biochemical genetic screening molecular systematics genetics (method to measure diversity) DNA storage technologies faster genomic technologies (shipboard) genetic sampling real-time remote analysis of genomics
Human Diving	Improve Capability Expand Capacity	cold water diving rebreathers/mixed gas saturation diving technical and advanced diving
Human Habitats	New Development Expand Capacity	mobile habitats Aquarius and other habitats long term observatory

Category	Desired Action	Technology
Imagery and Video	New Development	acoustic/laser vision systems Cave Cam (access through cracks & small openings) self cleaning camera lenses
	Improve Capability	confocal microscopy Critter Cam digital camera systems digital cameras HDTV & holography image recognition and software IR laser scan laser imaging light meters and other monitoring equipment low light cameras motion sensor cameras photomosaics rugged low light cameras strobe frame photography for time series analysis thermal imaging time lapse imagery tomography video image classification techniques
Marine Archeology	New Development	facilities for preservation & stabilization of artifacts tailored AUV for archeological assessment
	Improve Capability	archeological tools artifact removal tools non-destructive investigation techniques shipwreck integrity tools
Other Data Sources	Expand Capacity	ARGOS Hawaii Undersea GeoObservatory (HUGO) at Loihi volcano hyperspectral imaging from aircraft National Technical Means SABSOON network expansion

Category	Desired Action	Technology
Platforms	New Development	AUV "garage" AUV stationed underwater - "wake up" AUVs that follow targets dedicated submarine dedicated swath vessel deep ROV/AUV (multipurpose) deep submersible high current-capable submersible networked AUVs next generation of FLIP NR-1 submarine-like vessel
	Improve Capability	adaptable control systems deep ROV dockable AUV's radio-acoustic positioning telemetry (RAPT) remote sensing technology on AUV ROV/AUV dynamic positioning systems slow moving, steady AUVs tailored AUV
	Expand Capacity	aerial survey Alvin and deep ROVs in inventory AUVs for mapping broad shallow areas of continental shelf dedicated ice breakers & ice capable vessels extended AUV range capability submersibles vessels of opportunity
Sampling - Biological	New Development	automatic release, pop-up fishing gear and sensors high pressure sample preservation migrating instruments miniaturized samplers reusable biosensors tracking biota with space-based remote sensors sampling tools to collect gelatinous organisms
	Improve Capability	AUV/ROV bait deployment bioprospecting tools capturing particle flux flow cytometers for microbe levels hyper-/multi-spectral optics (species ID) larval sampling tools measurement of energy flow thru life form systems non-invasive technologies to follow mammals nutrient sensors optical plankton counter phosphorescence sensors remote biota capture techniques sampling & stable isotope analyses for food pathways sampling and incubation systems for culturing organisms specialized tows for zooplankton upward looking devices to monitor water column water sampling, virology, bacteriology, molecular biology techniques

Category	Desired Action	Technology
Sampling - Chemical	New Development	microchemical sensors molecular level diagnostics and early warning
	Improve Capability	active fluorescence chemical characterization of sites using cores chemical sniffers environmental tracers fatty acid analysis gas hydrate sensors geochemical measuring systems higher resolution chemical sensors neutrally buoyant chemostats optical spectrometer sensors for gas analysis
	Expand Capacity	long term chemical sampling (e.g. osmosamplers)
Sampling - Geological	Improve Capability	geologic porosity instruments remote drilling pressurized hydrate cores
Sampling - Physical	New Development	adaptive sampling instruments laser linescan technologies to direct sampling surface deployed, deep sampling/analysis devices
	Improve Capability	corers/vibracorers deep ocean sampling instruments drifting sediment traps (vertex style) improved suction samplers neutrally buoyant sediment traps nuclear magnetic resonance for sediment analysis remote manipulator rock dredging sediment coring sediment traps smaller tools (bore hole size)
Sensors - Acoustic	New Development	acoustic techniques for benthic classification synthetic aperture sonar
	Improve Capability	acoustic biomass acoustic imaging of sediment layers acoustic mapping (single/multibeam) acoustic monitoring (biologics and geologics) acoustic tagging of biota better/faster multibeam systems forward scatter acoustic techniques interferometric sidescan sonar multibeam bathymetry towed arrays
	Expand Capacity	ADCP's sidescan sonar SOSUS

Category	Desired Action	Technology
Sensors - Deployed	New Development	instrumented "rock"
	Improve Capability	3-D/4-D seismic buoy networks drifters (SVP) ice moorings instrumented moorings long-term moorings multi-line arrays and multi-sensor arrays remote sensors for marine mammals satellite tags on spawning fish
	Expand Capacity	permanently moored data buoys seismometers
Sensors - General	New Development	automated sensors hyperspectral techniques intelligent sensors micro- and nano-technologies miniaturized exploration / sampling techniques small scale air/sea interaction sensors
	Improve Capability	flow thru system gravity survey heterogeneous area sampling improved RADAR and LIDAR magnetic sensors mass spectrometry plume prospecting sensors pop-up satellite archival tags (PSATS) profilant floats radiological sensors resistivity sensors salinity measurements sea-floor probes sub-bottom profiling towed geo/chem/bio sensors vertical array sensors water column sampling
Sensors - Hardened	New Development	heat flow sensors extreme cold technology
	Improve Capability	biophysical moorings (winter) low temperature containers high temperature sensors
Sensors - Hull Mounted	New Development	bow mounted microwave radar
	Improve Capability	shallow water fathometers

Participants in multiple regional workshops identified common ocean exploration technology needs. This set of technologies likely represents the highest collective priority among the workshop participants and may be considered representative of the interests of a multidisciplinary group of ocean exploration advocates. These common interest technologies are included within the following themes, listed without regard to priority:

- AUV technologies including associated sensors and tools, command and control capabilities, communications, navigation systems, and deployment and recovery mechanisms
- Deep diving (greater than 4500 meters) submersible and ROV assets
- Dedicated surface-based exploration platforms
- New and expanded high resolution (~1 meter horizontal and 0.01 meter vertical) bathymetric mapping technologies
- New high resolution digital imagery and video technologies in natural lighting conditions and in a variety of electromagnetic spectral bands
- New and improved miniaturized, adaptive, tailored, and remotely or robotically operated tools for physical, biological, geological, and chemical sampling
- New tools for archeological assessment, artifact recovery, and preservation
- Innovative in-situ and remote sensors and tools to support genomic, biotechnical, bioengineering, and microbiological applications
- Improved precise positioning systems for platforms, vehicles, and deployed sensors
- New and improved sensors designed for use in extreme environments
- Systems supporting increased depths and residence times for human diving
- Intelligent sensors for detecting, characterizing, and tracking pelagic biota
- Improved data collection, processing, and visualization capabilities

4.3 Benefits

This section summarizes the potential benefits to be gained through the satisfaction of ocean exploration needs from the perspectives of the workshop participants. The benefits were derived from discussions relating to the relevance of specific exploration needs, and the resulting information in this section has been consolidated and standardized from the raw workshop data. The benefits have been organized within the themes of science, industry, outreach, and regulatory policy. This section provides a detailed summary of these benefits by theme, followed by a consolidated, categorical listing in Table 4.3.

4.3.1 Scientific Benefits

The scientific benefits include advances in science knowledge from exploration that lead researchers, technologists, and others towards asking the right questions and guide them to solutions. Ocean exploration provides information in undocumented or unknown areas of science to allow comparisons and definitions of changes to the planet. The lack of

documentation and inventory of the complete environment and insufficient high-resolution maps of oceans and coastal areas were the most frequently mentioned needs for conducting exploration. Scientific benefits were discussed more than other benefits and generated the most response due to the professional backgrounds of workshop attendees. The benefits are provided by exploration needs category in alphabetical order.

- *Archeology*. Archeological benefits include, but are not limited to, knowledge of historical effects of anthropogenic influences on ocean resources including rate of change, the chronological record of mankind and its exploitation of the sea, and historical migration routes of humans. Discovering the historical record also includes identification of potential cleanup sites, protection of historical sites, and identification of paleo-sea level changes. Archeological pursuits help to refine questions about where the human culture is heading and identifies socioeconomic and cultural use of the oceans in the past so that its past use on present ocean conditions can be determined.
- *Artificial Reefs*. Exploring artificial reefs leads to discoveries of the interactions between reefs and their environments and helps characterize the identity and distribution of biota and invasive species. It also supports an understanding of the role of ocean and coastal underwater structures and how they affect the life cycle of fisheries.
- *Benthic Regions*. Benthic regions are difficult to observe and thus are not well understood. The discovery of new benthic species is nearly certain, along with information exposing the earth's history and proxies for understanding sediment records and crustal processes. These regions also provide a link to understanding climate change. Exploration of the bottom can lead to an understanding of the reasons for failing fisheries and dependencies in fragile ecosystems such as the Great Lakes. Exploration can produce knowledge of bottom dwelling fish in the food web, including their life cycle and processes that may be limiting recruitment. Placing the deep Gulf of Mexico into zoogeographic context may generate biotech applications and help define genetic makeup.
- *Air-Sea Interface, Currents, and Water Masses*. Air and sea interaction, currents, and circulation are drivers of ocean changes. Ocean exploration provides an ability to assess impacts of these changes on habitats, ecosystems, productivity and eventually global climate change and other global processes. These assessments can be accomplished at macro and microbial scales. The ability to assess these impacts requires observations that have not been collected before. Data from exploration activities can drive the development of ocean prediction and circulation models (small scale processes in the water and air). Using lakes (e.g., Great Lakes) as a model of a closed system will allow for logistically easier study of climate impacts and the transport of toxics and nutrients. Relevance to societal needs (e.g. global warming to trend prediction) is also a benefit. Exploration facilitates tracking of

biological changes and food production (larval transport), and provides a way to bring together the modelers and researchers conducting empirical measurements (pattern recognition). In the Arctic, little is known about one of largest nearly fresh water reservoirs (a gyre) capable of influencing global climate. Unknown species and processes, and nutrient distributions are characteristics of these gyres that help to understand transportation of fish populations and other organisms. The information also helps to understand and predict biohazard and geohazard events, as well as conduct impact assessments

- *Coral Reefs*. Conducting a complete inventory and mapping of deep and shallow coral reefs is an exploration mission with many short and long term benefits. They include understanding the trophic connections, impacts of diseases, and the role of corals as ecosystems and as commercial fisheries habitats. This knowledge can assist in management of these areas leading to enhanced species diversity. New species will be identified. Extremely cool, and very old deep coral information will contain excellent deep-sea climate records (deep sea climate gradients) and are loaded with bioactive chemicals. Corals are also the centers of biodiversity in shallow waters and a target for genomic studies to support bioengineering.
- *Ecosystems in Abrupt Topography*. The benefits of exploration of ecosystems in abrupt topography regions were of high interest during the workshops. There is a lack of basic spatial and temporal understanding of ecosystems. Inventories associated with ocean exploration could populate a considerable number of information gaps. Oceanographic research programs overlook many remote areas with highly variable habitats. Ecosystem inventories would support data collection needs in biodiversity, ecosystem interactions, biological community structure, and management and restoration issues. Inventories will identify pollutants and their sources and transport mechanisms. From inventories of possible resources in shallow water to unexplored dynamics of the nepheloid layer, new information on deep water coral communities, baroclinic effects, nutrient production, and biological productivity will contribute to new discoveries about many different and unusual ecosystems.

Systematic changes occur along island chains due to their shape while other abrupt areas force very dynamic changes on the physical environment. The abrupt topography regions include geographic features such as arcs, canyons, canyon systems, depression areas, major subduction zones and trenches, fjords, submarine seamounts, ridges, associated unknown biological hot spots, ridges in heterogeneous lakes, pinnacles, and reef edges. Also included are vents, seeps, volcanoes and marine caves. Knowledge of impact of seamounts on ocean dynamics is another unknown area with influences on ocean circulation. A unique gravel cobble bottom feature and associated habitat is an example of a continuous feature that is not well documented. Ecosystem exploration in abrupt topography regions provides benefits to the understanding of submarine volcanism, strong current habitats, animal migration issues, and other intense fisheries issues. This exploration is key to understanding the distribution of sediments, the knowledge of depositional cycles, the impacts on marine mammals and nutrient production, and the knowledge to resolve history of continental margins, and effects on oceanography and biological assemblages.

Exploration inventories of abrupt topography regions in geological, topological and biological coupling, foraging, and upwelling helps to explain facets of maritime geologic history and particularly Pacific plate evolution. Emerging landscapes are often extremely dynamic with many opportunities to leverage off of other studies in these areas. Unique ecosystems, species, trophic systems and food webs thrive in centers of upwelling. There are also recolonization issues, such as following a biologically related catastrophe. Fundamental dynamics knowledge is needed for understanding roles of these regions as biogeographic "stepping stones". Discovering the biodiversity of these areas can also lead to potential conservation areas.

There is significant potential for hydrothermal activity at troughs. Workshop participants felt it important to understand equilibrium in the untouched communities of troughs before disruption, trying to understand how they evolved thru time by measuring the duration of settlements in any one spot. Discoveries could include unique species with bioengineering potential.

Trenches and Arcs, although similar to troughs, were a major emphasis in the Hawaii and Alaska regions. Discoveries of gas hydrates, chemical plumes and fluxes and unusual biota are expected in the Tonga Trench and Tonga Kermadec (less than 2% has been explored). Mapping and inventories of volumetrics, geologic signatures, ocean circulation vectors, plate tectonic boundaries, the deep water column as well as the subduction factory will reveal mineral resources, and variations of biomass in an oasis of life. These types of areas are huge opportunities for fundamental discovery of bioactive compounds, health in the deeper coastal zone, biotechnology, genome mapping and modes of life.

Other abrupt topography regions of interest are marine caves, vents, seeps and volcanoes and other extreme environments. Vents seeps and volcanoes are similar to marine caves as unknown areas with very little information on their distribution. Inventories of all taxa, living fossils, and biodiversity will discover unknown exotic organisms and new links and insight into the deep sea and the evolution of life. Every vent appears to be a bit different with most species endemic but exhibiting an extensive biodiversity. Knowledge of them is key to understanding active volcanoes, gas chemistry, and hydrothermal geography. New knowledge of genetic links between biota from different areas will provide fundamentally new insights into evolutionary science.

- *Ecosystems in Basins and Banks.* Exploration in banks leading to basins that go to great depths over short distances will reveal large amounts of interesting information regarding geology, shipwrecks, carbonate bank evolution and unknown "whiting events" possibly from calcium carbonate in the water column. Inventory of fisheries will provide connectivity and species dispersal to other unexplored regions. Other benefits include clues to sea level change, general coral reef health information, history of major islands such as Hawaii, and identification of new habitats. Other areas that are not well documented include Alaska's glacial scoured areas and channels.

- *Ecosystems in Extreme Environments-Sea Ice.* Sea ice areas and the marginal ice zone are not well understood and have important biological potential. Exploration will identify new species and novel protection mechanisms against extreme conditions. Many birds and mammals spend winter in the Bering Sea and Aleutian Islands but little is known about their food web dynamics. The Alaska workshop participants consider Bering Sea ecosystems to be at risk due to diminishing annual extent of sea ice, which is believed to play a critical role in the shelf ecosystems. There is an unknown balance of physical and biological processes associated with ice dynamics and changes in ice distribution for climate response issues will benefit from exploration.
- *Ecosystems in Lakes.* Large lakes are a major resource for fresh water. The Great Lakes have considerable deep and bottom areas that are largely unexplored. Benefits from exploration include finding and understanding new species and understanding the origin of the lakes themselves. River run-off, linkages between estuaries and river fauna, biota and their habitats, complexity issues unique to the freshwater lakes systems, and potential sources of groundwater input are important to science and our way of life. The unique and unknown evolutionary aspects of microbiology in fresh water lakes may help in bioremediation. Ring depressions are largely unexplored yet are the most widespread feature on the floor of North America's largest lake.
- *Ecosystems near Shorelines, Ledges, and Slopes.* These ecosystems are significantly impacted by humans and not documented nor inventoried enough to help scientists ask the right questions. The remote nature (Alaska) and the unique meeting of water currents (South Atlantic) are examples of productive areas for exploration. Baseline inventories and surveys will provide information for hurricane impacts (coastal hazards such as erosion, rapid response to natural or man-made catastrophic events), essential fish habitat knowledge, and paleoshorelines including coastal evolution, knowledge of substrate, benthos, habitats and their relationships. Understanding of unknown ecological systems, behaviors, energy flow, status and impact assessments, bottom health, and flux of nutrients will contribute greatly to defining and locating future Marine Protected Areas and their functionality. New knowledge and a better understanding of slopes will serve to benefit impact assessments, identify new species and biodiversity, identify upwelling zones, and provide a baseline characterization of productive areas for essential fish habitats. Knowledge from exploration will also assist in the understanding of the influence of the Gulf Stream.
- *Episodic Events.* Information from exploration of episodic events would be collected on event driven storms, surface and benthic storms, algal blooms, distribution of nutrients, coastal processes, the synergy of impacts and mitigation, hypoxia phenomenon, and currents related to the formation of harmful algal blooms. Benefits derived from a plate scale to mesoscale (gyre scale) observatory for long-term understanding of episodic events would open a new temporal domain, resolves limitations of surface vessels, and establishes a new paradigm of sampling in time and space providing an interactive telescope into inner space.

- *Geology and Geomorphology.* The areas of plate boundaries, strike-slip systems, glaciers, and the characteristics of the environment created from glaciers are not well understood. The fresh water inputs to the ocean and consequences of rapid glacier retreat are also not well documented. An examination of variability in the global record is needed to help determine if human activity is changing our environment. High-resolution maps are required to identify and characterize shorelines and reefs, develop baselines for geology, and to locate other important geomorphologic features. Benefits include the identity of mass-gravity movement, turbidity flows, hydrate beds, slope instability, paleoclimate changes, sea floor habitats, beach deposits, canyon formation processes, and anthropogenic factors. Exploring the megafurrows in Gulf of Mexico and Great Lakes can provide impact on currents, sediment transport and habitat issues. Other benefits are possible from higher resolution surveys such as the discovery of new features and biota, new essential fish habitats, new lake processes and boundary conditions and insights into deep-water circulation and sedimentation patterns.
- *Human Impacts.* Workshop participants discussed exploration into the human impacts on the ocean as a significant impact on the health of the planet, from ecosystems health to the impacts of anthropogenic noise. The science of understanding human impacts may resolve information relating to competition for resources and habitat loss and degradation of fishing. Exploring natural and anthropogenic noise can lead to use of natural noise as a measure of ecosystem and constituent health.
- *Marine Conservation.* Little is known about proposed marine reserve regions. Most are deep regions, greater than 50 meters depth, and have a role in supporting ecosystem spawning. Knowledge of these proposed areas from exploration has many benefits, particularly related to regulation. For example, exploration could reveal impacts such as the destruction of deep corals in the Oculina Banks from trawling and dredging, in this case leading to designation as a Marine Protected Area and closure to fishing. Exploring this area and others like it will provide knowledge of unique habitats and an assessment of restoration techniques. More knowledge is needed to demonstrate the effectiveness of Marine Protected Areas in restoring corals and fish populations.
- *Marine Microorganisms.* Fine scale knowledge of microbes is an important objective for ocean exploration. They are the most abundant organisms in the marine environment, playing a critical role in the function of ecosystems and the control of biogeochemical cycling. Knowledge of microscopic interactions and microbial roles in ecosystems will benefit science in knowledge of ecosystem health, long-term variability, production of biochemical compounds, and changes affecting ocean productivity. Exploration will help in documenting the life cycle of parasites, primary and secondary hosts, and improve the knowledge of their effects on carbon and phosphorus cycling.
- *Marine Organisms.* Data gathered from exploration will benefit knowledge of migration patterns for high-latitude organisms, how animals use vision & light to

orient themselves in the water, populations in flux, biological transitions zones, understanding exotic invasive species, and the distribution, migration, and abundance of gelatinous plankton. Knowledge of these organisms will help to identify critical habitats, their utilization, and will help identify global climate change. A taxonomy inventory is necessary to determine the marine biodiversity and ensure the benefit of preservation of species. Benefits will be derived from new knowledge of novel feeding relationships, survivability, and genetic and chemical diversity. New feeding relationships could reveal major sources of nutrition and lead to new biological linkages. Workshop participants principally discussed macro organisms, but recognized that pelagic plankton represented the dominant biomass in the ocean.

Exploration can benefit fish populations and fisheries by the scientific knowledge gained. Discovering and collecting information about distribution of marine geographic endemics, abyssal fish, fish evolution in isolation, inter-lake comparisons, and species migration can benefit the management of newly discovered or exploited species. Little is known about gene flow problems, recruitment problems, larval dispersal, distribution, and stages, invasive species problems, displacement behavior, life cycle and history, impacts of the amphipod diporeia decline, and island and region biogeography. The benefit of understanding the importance of upwelling will help to explain or predict recruitment to fisheries, effects on estuarine systems, define unique habitats and locations, and understand the dynamics of fisheries and ecosystems.

Exploration of marine mammals includes discovering and collecting information about distribution, movement and behavior patterns, orientation, and abundance of deep diving and long-range mammals. Additional benefits include information about food sources and distribution linkage including vertical migrations, habitats of large pelagic animals, the identity of obscure, unknown animals, population success rates, interactions with ocean structures, and use of habitat and navigation mechanisms.

- *Ocean Resources – Bioprospecting and Minerals.* Bioprospecting has benefits to both scientific and industry. There is a high likelihood of bioprospecting success from knowledge of the local biodiversity and molecular content in around coral reefs and other remote ocean regions. An inventory will provide baseline knowledge of candidate locations for further study. Knowledge of renewable resources such as gas hydrates and the discovery of deep sea minerals support knowledge of the impacts of these resources on climate change, carbon cycle, geohazards and sea floor stability, and fluxes of material through the sea floor.
- *Pelagic Environments.* Mid-water exploration can lead to significant benefits, particularly the identification and characterization of the largest ecosystem and biomass in existence. This exploration can also help define the composition of the pelagic realm and resources that need to be conserved or exploited. Other benefits include discovering unknown interactions in the water column, new species, carbon cycles processes, baseline data for rapid response to blooms, micro level knowledge of ocean processes, contributions to the food web, and knowledge of spawning and distribution patterns.

- *Sound in the Ocean.* Characterizing naturally occurring sounds in the ocean and using the technology of acoustics to support exploration can lead to new discoveries across all of the oceanographic disciplines. It will also support the development of innovative sensor systems.

4.3.2 Outreach Benefits

Outreach benefits are centered on education of the public of our marine environment so as to ensure its proper use and conservation through stewardship. Education of maritime and marine history, technologies in use in the ocean, and effective preservation methods were emphasized in the workshop discussions.

- *Education.* Education specifically includes targeted efforts towards K-12, undergraduate, and graduate level students. The products of ocean exploration are very visual and provide the media, academia, and industry with the material to educate the population and support a robust tourism, ecotourism and water quality industry as well. The adventure of exploration can excite the public by showcasing a "new frontier" that emphasizes the discovery of new organisms, biotechnology development, and new areas of research. Through the Ocean Explorer web site and related sites, expanding computer literacy can be associated and related to science. Other vehicles for outreach include opportunities aboard cruise ships for educational lessons. Opportunities must be organized to get students and teachers out to sea in relevant regions. The education of entire communities may be possible by tailoring public education, such as by encouraging graduate students to focus on ocean issues of local public concern. Data from ocean exploration can be incorporated into curricula such as geographic information system classes. Additional opportunities exist with public interest in the history of Hawaii regarding extreme environments as attractive and unusual topics for media and education.
- *Stewardship.* Stewardship of our cultural resources was included as a significant benefit from exploring our ocean's potential and existing historical sites. Strong education initiatives will build the core public interest towards stewardship of the ocean environments and merge with public safety issues about the oceans and beaches. This issue has some visibility with the public through publicity about invasive species and harmful algal blooms. The public also has an interest in biotechnology products, beach recreation, fishing, pharmaceutical potential of marine resources, biological warfare against infrastructure assets such as power plants (e.g. zebra mussel issue), operation of municipal water plants, and even carbon cycling. Knowledge gained through exploration may appease public concerns and activate mitigation efforts towards safety-related ocean issues such as tsunami predictions, fisheries sustainment, and unauthorized dredging. Conservation of the environment can be sustained through effective and safe use of newly discovered deep-sea natural resources.

4.3.3 Industry Benefits

Industry benefits include improvements in capabilities, expanded products and markets, more economical methods of doing business, and improved safety in the ocean environment. These benefits also indirectly expand the public interest in the ocean and its potential. Ocean exploration will support technology development in a wide range of industries including those related to water resources, tourism, fisheries, bioprospecting, and energy.

- *Water Resources.* A unique connection between industry and scientific knowledge is the importance of understanding fresh water resources. The dynamics of lake environments and their freshwater resources were emphasized in the Great Lakes workshop since these lakes contain most of the fresh water resources of the world. Physical oceanography knowledge gained through exploration leads to an understanding of many ocean and lake processes. Water level variations of the Great lakes can significantly impact navigation and the commercial shipping industry. Exploration data could benefit the interests of entities seeking knowledge of the Arctic's potential to support routine commercial shipping.
- *Tourism.* The products of ocean exploration are visually appealing and provide the media industry with material to educate and support a robust tourism industry. Industries that may benefit from these products include sport fishing, recreational fishing, diving, beach maintenance, cruise lines, and ecotourism.
- *Fisheries.* Knowledge of deep-water fisheries, inventories of fish habitats, and identification of new species will aid in building linkages between commercial and recreational fishing interests. Ocean exploration data will aid in applying fundamental ecological principles to the establishment of new fisheries and general fisheries resources. The SAFMC (South Atlantic Fishery Management Council) was identified as a direct beneficiary of ocean exploration information. Fisheries management benefits from exploration data through better stock assessments and understanding essential fish habitats.
- *Bioprospecting.* Exploration data has huge potential to provide many advances in biotechnology and its applications to the pharmaceutical and seafood industries. Genome mapping, discovery of modes of life and biotoxins, and a wealth of other information may be available. Unique species with biochemical properties may serve as areas of production "oases" for new bioengineering products. Bioprospecting, habitat mapping, and discovery of new natural resources will also benefit ocean resource management.
- *Oil and Gas.* The energy industry will benefit from the improved baseline knowledge of the seafloor and its natural resources. There is particular interest in areas where ecosystem management and restoration issues are critical to sustainable

environments. These issues are coupled with the potential discovery of new natural resources. There is general recognition that methane deposits in the form of hydrates could have huge potential as an energy resource if they could be recovered economically. Other important mineral resources may be discovered as well. Possible coldwater petroleum seeps might be discovered in unexplored areas near abrupt topography. The Gulf of Mexico may be unique with amount of oil naturally occurring in this region.

- *Other Economics.* The cost of business for the communications industry will improve from the use of exploration data for cable laying efforts. Aquaculture will benefit from the scientific data collected from ocean exploration. New business is likely to develop around new opportunities resulting from ocean exploration efforts.

4.3.4 Regulatory Benefits

The process of developing regulations, policies, and legal mandates can be accomplished more easily and correctly as a result of the benefits of ocean exploration. Specific benefits include properly prioritizing sites for recreational, archeological, historical purposes, nominating designations to the national register, and cultural resource management.

- *Marine Protected Areas.* Marine Protected Areas contain critical ecosystems, important resources of high trophic-level organisms, and are subject to controversial fishery restrictions. Inventories and knowledge of these areas gained through exploration will be critical to the regulatory process.
- *Fisheries.* Ocean exploration information will provide a better ability to monitor the impact of fishing and other disturbances on fisheries to provide for better protection and management of sustainable fisheries. The deep ocean will reveal new benthic fish populations. Some species may be endangered and ocean exploration data can assist in determining the effectiveness of fishing restrictions, the seasonality of fishing areas, safety measures, and expected costs of containment controls such as structures and artificial reefs. These efforts support the Endangered Species Act, the Marine Mammals Protection Act, and the Census of Marine Life (CoML).
- *Conservation.* The conservation of natural resources requiring protection and sustainability will benefit from ocean exploration data. Some of these areas have the largest information gap and therefore have huge management implications. Coastal areas need protection from storm surge, loss of wetlands, and encroaching habitats. Information on water quality, contaminants, and marine ecosystem health will ensure that constituents and coastal zone managers have sufficient knowledge to support correct management and enforcement policies. International policy cooperation is also necessary and dependent upon ocean exploration data for information related to the impacts of waste dumping and other practices. Ocean exploration information can

benefit a wide range of other regulatory efforts with social and economic relevance such as regulation of shipwrecks, safety of life and property, pollution impacts, remediation of habitats, counteracting bioterrorism, and homeland security. Public health regulations and land use policies governing watersheds and coastal erosion zones will also benefit.

Table 4-3. Regional Workshop Exploration Benefits

Category	Workshop	Exploration Targets	Description	Benefits
Archeology	Regions: Alaska Caribbean Gulf of Mexico North Atlantic West Coast	Submerged cultural resources and maritime cultural environment; Shipwrecks including, pre WWII, WWII and Later Human Sites, Archeological Information on Human Migration, and basin and human interactions	Regional Archeological Assessment: Location, inventory and characterization of historical sites; documentation of artifacts and ancient villages; document effects on ecosystems and food chain, migration routes, dump sites; Document ice records. Characterize by Biological / Geological / Chemical; Document status of wrecks; recently uncovered by storms, etc. using systematic surveys or target submersible historical shipping lanes; sub-bottom formation identification of targets; consistent survey of coastline areas out to EEZ, record of sea level change; photo documentation;	Scientific: To assess effect of anthropogenic factors on ocean resources; Document chronological record of "mankind in the sea", migration routes of humans, Identification of potential cleanup sites; protection of historical sites; paleo sea level changes-assess rate of change-how humans and environments respond; insight into development of technology; Caribbean colonization. Where are we heading? Outreach: education of marine history; more effective preservation methods; Regulatory: Legal mandates; prioritize sites for recreational, archeological, historical purposes; designations to national register; cultural resource management
Archeology	Regions: Great Lakes Hawaii	Cultural resources; Paleo Archeology of basin and human interactions - survey and documentation; Understanding population from geological records; Extinct species (fossil reefs) Understanding the human habitat	Identify shipwrecks; Submerged shorelines; Paleolake lines, ID sites, location, archeological documentation, evolution of marine technology, 19th century, effects on biology (good time measurement), influence of currents, Broad based survey; then document important sites; model storm data; Study fossil and carbonate samples and records, population over geologic time; Mapping	Scientific: From earliest archeological sites in region, obtain a better understanding of prehistoric life & technology; Industry Increase connections to fresh water and appreciation of Great Lakes resources; Understand dynamics of region, Outreach: public interest, K-Grad, unlimited, more for prehistoric, Regulatory: Largest density of shipwrecks & submerged cultural resources, need to be protected & managed

Category	Workshop	Exploration Targets	Description	Benefits
Archeology	Region: Hawaii Atlantic North	Submerged archeological sites; Natural history of Hawaiian Islands; Character of Deep Water and other Archeological sites; Shipwrecks (5-10K off New England); Shipwreck Aggregation Sites	Near-shore low impact visual survey - Targeted historical research, archives, non-invasive documentation, geological controls on marine biota and communities; Mid-water remote sensing - narrow down to select survey areas, Deep water - survey targeted areas then ground truth; structures; cultural resources; Priority to older targets; ID location, & characterize paleo geography	Scientific: - Not well documented; in state and federal laws that historic vessels are to be protected; Marine resources; Better maps; Hazards issue, Industry - tourism; salvage Outreach: - lots of public interest, education, stewardship of cultural resources; Regulatory: - mandate for protecting areas;
Artificial Habitats	Region: Great Lakes Gulf of Mexico	Artificial Reefs; Offshore man-made structures	Recruitment, deterioration of cultural material, environmental effect, new vs. used; Zoogeography of man-made offshore structures - oil and gas structures with time-based observations (depth is a very important component; systematic approach); oil and gas structures; Sargassum mat time-based observations at rigs (modeling; observe before and after mats pass rigs); taxonomy; diversity; distribution	Scientific: In fresh water can do well controlled experiments; How reefs interact w/environment? Characterization and distribution of biota; invasive species; understanding the role of these structures +/-; how do they affect the life-cycle of fisheries; are they just FAD's; little known Industry: aquaculture, recreational diving, biofouling research, charter boat industry (sport fishing); resource management; pro's and con's of platform removal; provide other options for platforms not in use; biotech applications; resource management Outreach: very visual & interesting to the public. Regulatory: depends on results, should they be doing it or not;

Category	Workshop	Exploration Targets	Description	Benefits
Benthic Environment	Region: Alaska Hawaii	Relationship of Benthic Features and Essential Fish Habitats; Infaunal organisms	Catalogue the distribution and abundance of the types of species that are in the mesopelagic zone; document the benthic habitats that support important ecosystem components including fish and rare or special species and essential fish habitats; Taxonomy, investigate sediment ecology	Regulatory: MPAs; fishery restrictions; critical ecosystem; important resources; critical resource of high trophic level organisms (big fish, birds, mammals)
Benthic Environment	Region: Great Lakes	Benthic Communities "Things that live between the rocks" - Limited sampling of difficult areas; Deep Reef systems; out crop reefs; Identify & characterize interaction, effects of exotics, impact of fisheries, compare w/ oceans, food web	Sampling of difficult areas; Deep Reef systems; out crop reefs; Identify & characterize interaction, effects of exotics, impact of fisheries, compare w/ oceans, food web; effects of exotics	Scientific: Undiscovered areas of bottom; finding new species in Great Lakes; Failing fisheries in lower Great Lakes, need to understand why: Lake Superior (untouched), fragile, have ignored benthic fishes in food web; knowing mating game, life history, what's limiting recruitment, learning more about diporeia decline. Industry: power plants (significant) (e.g. zebra mussel issue), municipal water plants, carbon cycling. Outreach: "huge", public concern, education need. Regulatory: fisheries management, water quality, contaminants

Category	Workshop	Exploration Targets	Description	Benefits
Benthic Environment	Region: Gulf of Mexico	Biology in deep benthos; Characterization of bottom habitats; infaunal organisms; Exploring the deep benthos for biological communities; broad scale characterization and inventory; genomic mapping - non-traditional; cataloguing for biotechnology; live bottom communities; match fish species with bottom character;	Ground truth via deep tow side scan sonar; deep Gulf of Mexico is most heavily studied soft bottom in world; sampling; trawls; subs; genetics; Gulf is a marginal basin - distinct zoogeographic province; mapping identifies hard surfaces - can't trawl or box core; so photo; ROV's; subs; geology important; non-chemosynthetic hard bottom poorly studied; looking for topographic highs; lithoherms; lophilia mounds; sink holes - topographic lows - have lots of fish and corals associated with them	Scientific: high likelihood of bioprospecting success; biodiversity; molecular; placing deep Gulf into zoogeographic context; biotech application; genetic makeup; Industry: Fishing stock assessment; Understanding essential fish habitats, bioprospecting; habitat mapping; government NIH; resource management; resource management; Outreach: new communities; sexy topic; can work this stuff into curriculums; video clips on internet;
Benthic Environment	Region: North Atlantic West Coast	Knowledge of Deep Benthic Community and abyssal plain	Not well documented Characterize, Biology, Geology, Bottom Interactions, Ecology Dynamics; Deep Cold Corals; Sweeping water column; Investigate by using Class I/II Vessel w/Acoustic Mapping; Dive Capability (ROV / AUV / Submersible) w/ Imagery / Video & Sampling Equipment (Not Only ROV / AUV / Sub); Multibeam; ADCP's; Precise Position System; Outreach Capability; Education Component - Fixed Sensors; Space-Base Remote Sensing; Biosphere at the seafloor	Scientific: Need to ascertain anthropogenic impacts; not well known, know how ocean works; discovery is guaranteed; earth's history; proxies to understand sediment records; simultaneous process documentation over a decade opens the door to millennium; crustal processes compared to other planes; link to climate change
Boundary Fluxes - Air/Sea	Region: Caribbean	Air/Sea Interactions on the small scale	Document the biological, chemical, and physical processes of the air/sea interface in high resolution over a small area	Scientific: Help us understand the uncertainties of global change and other global processes at the microbial level

Category	Workshop	Exploration Targets	Description	Benefits
Boundary Fluxes - Air/Sea	Region: Great Lakes	Linkage in the atmospheric forcing function; How climate varies in space and time Carbon Cycling in Lakes; primary productivity, Carbon accumulation, Carbon consumption, compare among lakes. Each lake is a comparative experiment	Forcing functions in atmosphere; Air/Sea interaction for the exchange of gas mass constitutes; Across all lakes, measure physical properties, real time chemical composition (monitor 5 places in one of the large lakes; see how lake responded over two years and choose detailed location and study eddies and zooplankton modeling); Application for marine boundary levels influences; Different processes to study and couple to ocean processes cores and eddy's (rings); Climate Changes on timescales of decades to millennium. Compare carbon cycling, primary productivity, and carbon accumulation, among lakes	Scientific: Driver of Ocean changes; Using the lakes as a closed system for the development of prediction models (small scale processes in the water and air); Easier to study (logistics) the effects of El Nino and global warming; Lake circulation and variation questions; Better understanding of sediment record for paleoclimate, transport of toxics & nutrients, fish recruitment. Relevance to societal needs (e.g. global warming to trend prediction), higher resolution than ocean cores; Industry: Lake level variations impact commercial shipping; Outreach: Education, Inspiring kids, Computer literacy related to science vs. games; Connection w/ boaters; Regulatory: Major impact on lake level and fisheries management, Tourism protection, Water resource management; Test hypothesis of carbon cycling.
Boundary Fluxes - Air/Sea	Region: Gulf of Mexico	Air/sea interactions; Dynamics of interaction between water masses	Understanding impact of significant weather (hurricanes; tropical cyclogenesis) on deep ocean; characterize ocean under severe weather and ocean bottom in real-time	Scientific: ability to assess impact on habitats; geomorphology; and ecosystems; has not been observed before; benthic recovery; determine if relationship between tracks and water; hurricanes generated in Gulf; short-term warnings; Currently understanding lacks sufficient scale and depth; Identify impact on productivity Outreach: education; science; Regulatory: risk assessment safety

Category	Workshop	Exploration Targets	Description	Benefits
Boundary Fluxes - Air/Sea	Region: Hawaii Caribbean	Climate Change; Impact of fresh water runoff & suspended/dissolved matter	Feedback of ocean change on biota - through observation approach time series with El Niño events: determine impacts on equatorial Pacific biological pump; long term; carbon fluxes in thermocline; Identify and quantity impact of fresh water runoff & suspended/dissolved matter	Scientific: Understanding biotic feedbacks on climate change; Predicting/modeling changes on impacts; Impact on ecosystems & habitats - Information on land use activities
Corals - Deep water	Region: Atlantic South Caribbean Gulf of Mexico Atlantic North West Coast	Deep sea coral mounts (oculina and lophilia); Distribution and status of deep water coral reefs and fish stocks; Knowledge of Deep and or Cold water Corals	Collect information on the distribution, taxonomy, abundance, condition, diversity, and size of deep corals and fish stocks; Assess threats and Map associated fauna; area; extent; size of mounds; new species; Investigate by using Class I/II Vessel w/Acoustic Mapping; Dive Capability (ROV / AUV / Submersible) w/ Imagery / Video & Sampling Equipment (Not Only ROV / AUV / Sub); Multibeam; ADCP's; Precise Position System	Scientific: bioprospecting, unknown, new species; Map and inventory deep reefs; trophic connections - how do they work?; Understanding of major commercial fishery habitat to assist in management; discover role in enhancing local species diversity; New species identification; Role in Ecosystems; Possible records of climate changes; Extremely cool; very old; contain excellent deep sea climate records (deep sea climate gradients); loaded with bioactive chemicals; Outreach: education such as live broadcasts, discover role in enhancing local species diversity; Regulatory; MPA implications; Industry: resource management

Category	Workshop	Exploration Targets	Description	Benefits
Corals - Shallow Water	Region: Caribbean Gulf of Mexico	Health and assessment of shallow water coral reefs; Turbid water coral communities	"Norms" (coral, fish, biomass) of condition for comparison; One time assessment; Presence and distribution; morphology	Scientific: - understanding of disease and impacts; biogeography; ground truth of remote images; center of biodiversity of shallow waters; emerging field of study; genetic info; influence of turbid water on benthos; Industry - fisheries; tourism; beaches; Major resource management issues; source of sediment for beaches, Outreach: Visible topic for media coverage
Currents & Water Masses	Region: Alaska West Coast	Circulation Survey: Need information on large-scale circulation and variability of Beaufort Gyre, Alaska; Need knowledge of ecosystem in primary & secondary fish production areas; understanding geochemical processes - target on eddies and boundaries of strong currents and upwelling	Document subsurface currents; Explore Beaufort Gyre as largest freshwater (almost) reservoir; Collect water column, physical data; use satellite imagery; collection of mid/bottom biologies; net and bottom sampling; connecting bio/chem/geo technologies and processes; eddy processes; ID drivers of production; lagrangian perspective; food web; ID sources and sinks, time signatures, and effects of human induced substances. Biogeographic cycling; inputs and outputs cycling	Scientific: Better understand benthic organisms, Understand how nutrients are distributed, and one of largest nearly fresh water reservoirs capable of influencing global climate; Previously have been unable to explore the gyre; Unknown species and processes; impact assessment; expands satellite tracking capabilities and real-time video; transmit broadband data; understand processes on other planets; Industry: fisheries management; management of living marine resources.

Category	Workshop	Exploration Targets	Description	Benefits
Currents & Water Masses	Region: Atlantic North Atlantic South Gulf of Mexico	Mapping currents and eddies and their connection to vertical and horizontal components; Exploring Gulf Stream, Loop current, and Florida Current; Knowledge of offshore currents impact on structures.	ID circulation; temperature discontinuities; current velocities; pH levels, HAB formations; Characterize; map; habitat assessment; nutrient cycling; life history/reproductive biology/evolution of life history, strategies of fishes, frequency and importance to ecosystem productivity, relationship between ocean prop. and hydrate stability; Use moored current meters at multiple depths; sediment traps; release drifters regularly from position on the sea floor and use satellites to track them; release drifters regularly from position on the sea floor and use satellites to track them, ID impact on engineering and design of structures.	Scientific: Understand and predict geohazard events, transportation of fish populations and other organisms; ID shipwreck status; Don't know much about dynamics of the Gulf Stream; Industry: storm warning and hurricane prediction; fishery; recreation; tourism; diving community; Outreach: huge educational/public relations potential, HAB predictions, biotech products; Regulatory: effectiveness of no fishing areas, seasonality of fishing areas; safety and containment control (structures), conservation management; safety and costs of structures; homeland security

Category	Workshop	Exploration Targets	Description	Benefits
Currents & Water Masses	Region: Great Lakes Atlantic North	Mesoscale Eddies/Fronts/Rings - frequencies & importance; Current flow patterns, eddies, mixing process, impact on bio, frequency & importance to ecosystems productivity, chem props; Discover new bio / geo /chemical pathways (distribution in the physical sense); Knowledge of physical and biological processes	Identify current flow patterns, eddies, mixing process, impact on bio, frequency & importance to ecosystems productivity, chem props; Identify pathways for compounds; place sensors at areas of gradients (biologically dynamic areas); ID intersections between layers, relationships to biota; Air-Sea Patterns / Interactions Impact of bottom boundary; Archeological Application; Magnetic Sensors; Data Mining; Bottom mapping & characterization capability; Develop new sampling protocols; Use Multi Line Arrays and Multi Sensor Arrays	Scientific: Need to understand input on ecosystem and nutrient and sediment transport; inference of global warming, correlation productivity, gene flow, recruitment, impact on benthic communities; fish recruitment; What compounds are influencing the environmental from remote area; Mass balance understanding in the Great Lakes; Contaminant Transportation; Coastal Meteorological models (Ground Truthing); Marine Weather Prediction; Fisheries. Industry: lake level variations greatly impacts commercial shipping directly. Outreach: std pkg, education, inspiring kids, computer literacy related to science vs. games. Regulatory: major impact on lake level and fisheries management, on tourism protection, on water resource management
Currents & Water Masses	Region: Great Lakes Hawaii	Coupling of Modeling and Measurements; Sample strategy/ bio / currents / Atmosphere models - Models can drive questions researchers to answers; Knowledge of changes to currents and internal waves.	Place sensors at areas of gradients, at biologically dynamic areas; track marine debris deposits. Determine food production distribution; Identify internal waves, and correlate tidal changes and other physical oceanography.	Science: Citizen science; Balance of empirical measurements with models; helps in planning with catch per unit effort; verifies the conceptual of the measurements that will be made; environmental predictions; tracking of biological changes food production (larval transport); provides a way to bring modelers and empirical measure researchers together (pattern recognition); physical modeling drives biology

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem	Region: Alaska Hawaii	Characterize Bering Sea Fish Habitats; Identifying ecologically critical habitats	Temporal / spatial observations; mapping; then direct observations; diversity; location; substrate type; visual information; reflected imagery; community structure; Locating critical habitats with Critter Cam (Animal borne camera) system; Use existing and historical information Use Bathymetry to understand sediments and habitat; Use hydrography for better understand of tidal data; Understand temporal nature of biology	Scientific: Lack basic information; Areas will not be looked at by other organizations; high variability habitat; Very important spatial gaps; Temporal gaps; Bristol Bay Alaska was home of most valued single species in world at one time; Hawaii: biogeography, biodiversity, ecosystem interactions, community structure, management, restoration; Oil and gas interest in the area; Industry: recreation, fisheries; Regulatory: reserves, management
Ecosystem - Abrupt Topography	Region: Alaska	Aleutian Arc	Examine the structural arc; Examine substrates and patterns of coral distribution; Document hydrothermal venting and volcanism; Document biodiversity, biology, and oceanography	Scientific: Understanding the geologically active areas that include submarine volcanism; Better understanding of strong current habitats and animal migration issues.

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Abrupt Topography	Region: Alaska Gulf of Alaska Atlantic North Atlantic South Hawaii Gulf of Mexico West Coast	Canyons and Canyon Systems; Unknown depression areas and canyon processes	Document rate of the consumption of the physical plate, geochemistry, sediment transport, and volcanism; Examine biology of area, and hot springs seeps; Examine these very interconnected physical systems; Inventory and document geology (improved mapping), Identify turbidity flow, erosion, and structure, microbial communities and other organisms, geochemical origins and effects; Map; characterize; ID mineral distribution; gas and groundwater seeps, sediment fluxes; chemistry; upwelling; ground truth, habitat role in carbon cycling, areas of high productivity	Scientific: Important area that is poorly characterized; Very systematic changes occurring along island chains due to shape; Dynamic physical system; Key to understanding the distribution of sediments; knowledge of depositional cycles; impacts on marine mammals; nutrient production; Is human activity changing the Gulf? Effects on adjacent ecosystems; unknown microbial communities and pelagic communities; origin unknown; inventory and characterize; potential for unexpected discoveries; Gulf characterized as a brine system - could be global question. Unique isolated habitats; resolve history of continental margins, and effects on oceanography and biological assemblages. History of Hawaii, Identify new habitats; Industry: fisheries, minerals, biotechnology; Outreach: public interest, lots of opportunity
Ecosystem - Abrupt Topography	Region: Alaska	Fjords of southeast and south central Alaska	Contrast recent glaciated landscapes to more stable and tidewater to non-estuaries; Compare tidewater glacial vs. nonglacial; Document substrates for habitat mapping; Detect species distributions; Determine some of physical and biological effects of deglaciation. They have complex oceanographic regimes and teasing out would be good.	Scientific: Intense fisheries issues; Marine Protected Areas establishment; Emerging landscapes that are often extremely dynamic; Lots of opportunities to leverage off of other studies in these areas; And lots of opportunities to have strong outreach component e.g. cruise ships; There are also recolonization issues, e.g. following biocatastrophe; Isostatic uplifting.

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Abrupt Topography	Region: Alaska Caribbean West Coast Great Lakes Hawaii Atlantic North	Submarine Seamounts, ridges and associated unknown biological hot spots; Knowledge of impact of Seamounts on ocean dynamics; Also other abrupt topography; North/South Ridges in heterogeneous Lake Superior;	Document evolution of seamounts, circulation, and currents.; Document ecosystems esp. in the deep water. survey triage of hot spots; different tactics for each hot spot; discover; inventory biota; explore; Identify processes; find new species, distribution of sediment & benthic communities, distribution of fish, influence of bottom currents, and deep seamount biomass; amounts; Conduct altimetry mapping comparisons; Geoid products; map, and ground truth. Sample and take direct observations with moored stations & deep dives; verifying location; measure deep scattering layer over hydro plumes	Scientific: Not documented or known well; Fundamental dynamics needed for understanding role as biogeographic "stepping stones"; Unique ecosystems; centers of upwelling; unique species; unique trophic systems and food webs; Discovering of biodiversity, potential conservation areas; Explains maritime geologic history; New species, dispersal, and evolution, biogeography, new habitats; Pacific plate evolution; topological / biological coupling; foraging, upwelling; fish migrations; Record of climate change in deep Corals; Industry: commercial fisheries, minerals, biotechnology; Outreach: Public interest, lots of opportunity
Ecosystem - Abrupt Topography	Region: Alaska Caribbean	Trenches: Aleutian Trench; Impacts of Underwater topography (Sea mounts, pinnacles, reef edges); Caribbean trenches	Inventory and document geology (improved mapping) and habitats esp. corals and methane seeps, document these trophic systems; Identify new species; ID hot spots of biological diversity; Caribbean: Exploration in trench region to understand the interactions between abyssal depths and shelf waters (including abiotic/biotic constituents)	Scientific: Possible feeding dynamics; possible resources in shallow areas; deep water coral communities for fish habitat; major subduction zone that is unexplored; Baroclinic effects; nutrient production; biological productivity; Unexplored; Identify geothermal activity; understand dynamics of nepheloid layer; Outreach: excite the public - "new frontier"; identify new organisms; biotech development; identify areas of research; Industry: deep water impact of fisheries habitats; cultural and historical data

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Abrupt Topography	Region: Caribbean	Understanding the ecology and oceanography of Florida Straits	Examine source water currents, pollutants, nutrients, and plankton	Scientific: Identify target areas for research; Identify pollutants and their sources/transport (ex. HABs); Identify new fisheries; Industry: Identify linkages between fisheries (including sources, sinks); management knowledge and resources; Outreach: ecotourism; feasibility of energy conservation
Ecosystem - Abrupt Topography	Region: Gulf of Mexico Alaska Caribbean Atlantic North Atlantic South West Coast	Topographic areas with biological communities	Time observation of topographic areas; revisiting topographic features that have significant biological communities; change in bathymetry; time lapse data	Scientific: access fish stocks; assessing changes in habitat and populations; species composition; Industry: resource management
Ecosystem - Abrupt Topography	Region: Gulf of Mexico	Lithohermes	Map; identify and characterize; geology	Scientific: Lithohermes not studied; may find deep corals on them; unexpected discoveries
Ecosystem - Abrupt Topography	Region: Gulf of Mexico	Cayman Trough	Mapping; plume prospecting; inventory and characterize; Identify deep corals	Scientific: significant potential for hydrothermal activity at the Cayman trough (active spreading center) and not mapped; can do it in a short amount of time
Ecosystem - Abrupt Topography	Region: North Atlantic	Gravel Cobble Bottom - continuous features vs. discrete; Gravel Windows - sediment disturbed & gravel exposed and not well documented	Not well documented	Scientific: Not well documented

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Abrupt Topography	Region: West Coast Alaska Caribbean Atlantic North Atlantic South Hawaii Gulf of Mexico	Banks; Fracture Zones; Subduction Zones; Canyons; Sea Mounts	Mapping; subsurface information; subbottom profiling; biosampling; currents; temperature; chemical description; cores to sample the microbial activity	Scientific: untouched communities to understand equilibrium before disruption; trying to understand how they evolved thru time (e.g. transient?; duration of settlement in any one spot.) unique species w/ biochemical properties; assessing connectedness among and between; genetic fingerprinting of some of the species; effects of exploitation
Ecosystem - Banks & Basins	Region: Atlantic North Atlantic South Caribbean Hawaii	Bahama Banks and deep basins	Survey and map; Explore mechanisms behind whiting events; sea level studies; geology; karst studies; low standing reefs; archeology - shipwrecks; reef studies; coral bleaching; carbonate production; reef sampling/coring for sea level and paleoclimate studies; ID highly migratory species and organisms; fisheries oceanography; many habitats to observe different regions; using ships, satellites; satellite based; remote sensing; satellite telemetry; critter behavior; sea level data; sediment traps; water column sampling; Document biogeography and taxonomy; Document physical, chemical, geological, and sediment characteristics	Scientific: Unexplored regions; new knowledge, increased understanding of climate/sea level change, see 'why'; Whiting events unknown - Calcium Carbonate in water column; lots of interesting geology; shipwrecks; goes to great depths over short distances - basic exploration; carbonate bank evolution; fisheries - provides connectivity to rest of Caribbean; general coral reef health; Industry: fishery; Biotechnology; Outreach: great opportunities; public interest; recreation; tourism; education; Regulatory: fishery
Ecosystem - Basins & Banks	Region: Hawaii	Solution Basins	survey, map, ground truthing, sampling, direct observations, ID and characterize organisms as well as features	Scientific -history of HI, ID new species, species dispersal, evolution, biogeography, ID new habitats; Industry - fisheries, minerals, biotechnology; Outreach -public interest, lots of opportunity

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Basins & Banks	Region: North Atlantic	Glacial Scoured Areas Channels	Not well documented	Scientific: Not well documented
Ecosystem - Caves	Region: Caribbean	Biodiversity and ecology knowledge of marine caves	Characterize and Identify biota using molecular genetics; Map; Determine chemical, geological, biochemical, and physical characterization, geology, Examine for archeological significance	Scientific: New and relatively unstudied ecosystems; Would identify new species and higher taxa; living fossils; most species endemic; potential for new life forms; potential links for deep sea; biogeography; evolutionary questions; genetic diversity
Ecosystem - Extreme Environment - Sea Ice	Region: Alaska	Characterize and explore Sea Ice areas and the Marginal Ice Zone; Wintertime trophic food web; Need long term Ice Dynamics; Info on sediment records; Map of sea ice coverage and rates of change.	Characterize and explore high salinity and low temp (cryosphere) environments; Map all oceanography features and content. Identify and catalogue the trophic webs and migration patterns that support birds and mammals in the wintertime; look at what physical processes impact their system; what zooplankton are available for species dependent on their food type; document water column biology (zooplankton); Document physical processes; Ballena studies; Increased fetch (expanded open ocean). Identify the role of sea ice cover in structuring the marine ecosystem; how does this vary with latitude; Systematic ice coverage surveys.	Scientific: Completely unknown and potentially Biotically important. Identify new species and novel protection mechanisms against extreme conditions; Many birds and mammals spend winter in Bering and Aleutians, but little is known about what they eat there; Better understand food web dynamics; Identify changes in ice distribution for climate response issues; Bering Sea is in an ecosystem crises; sea ice is believed to play a critical role for production of shelf ecosystems; predicted to diminish; Unknown balance of physical and biological processes associated with ice dynamics; Regulatory: Supports the Endangered Species Act. Outreach: Bering Sea Ice areas are cultural assets

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Extreme Environment- Vents, Seeps, and Volcanoes	Region: Caribbean Atlantic South Gulf of Mexico Hawaii	Find new vents and seeps (includes fresh water seeps), Need maps of content and locations; Montserrat in Gulf of Mexico; Hydrates and cold seeps/vents; sediment flows and biota; discover and document unknown active volcanism	Survey and document biogeography and taxonomy and discover new species and processes; Document physical, chemical, geological, and sediment characteristics; Map dead and living muscle & clam communities associated with seeps; Compare with subsurface; Understand the differences in communities between Blake Ridge and Gulf of Mexico; Document hydrothermal activity; Understanding the relationship between hydrates and cold seeps/vents and between sediment flows and biota (including microbes) and brine pools; discover new species and processes;	Scientific: - Unknown areas; similar to marine caves and all taxa biodiversity inventory lists; unknown exotic organisms; new insight into the evolution of life; every vent appears to be a bit different; Key to understanding active Volcanoes; Industry: also same but commercial benefits are less; Key to understanding the different impacts on habitats

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Extreme Environments - Vents, Seeps, & Volcanoes	Region: Gulf of Mexico West Coast Hawaii Atlantic North Atlantic South	Unknown chemosynthetic communities (subsurface - down several km); Microinvertebrate assessments; hydrate vents, seeps and vent communities	(Subsurface - down several km): oil seeps and vent communities; Inventory and characterize; isolated ridge system; new biota; larger geographic context; subsurface 3-D seismic surveys; biogeography (sample); locate plumes; Explore why communities exist; what turns these areas on and off?; Identify and characterize areas by Neuston tows; Microinvertebrate assessments e.g. kelp forest assemblages and soft habitat; microbial ocean; assemblages; interactions; predator/prey relationship	Scientific: very little info on distribution; gas chemistry (plumbing system); key biogeographic province for global hydrothermal geography; unknown regions; new biota; Provides new knowledge of significant communities through evolutionary time; global importance; genetic links between regions; Industry: may promote restrictions; resource management; biotech; may be unique with amount of oil naturally occurring in Gulf; biotech applications; pharmacological applications; gains (includes safety) in ocean management; fishing, potential new bioengineering products; serve as areas of production "oases"; ocean resource management (ex. protection of the communities); Outreach: Unusual topic for media; education. Regulatory: Homeland Security

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Extreme Environments - Vents, Seeps, Volcanoes, Trenches and Arcs and General Ecosystem initiatives	Region: West Coast Hawaii	Lack of microbial information at seeps; Understand formation of biofilm/microbial mat in extreme environments; Understand the Pacific Ocean regarding the origin of life (vent communities, any optimal environments, etc) Gaps in exploration in past of arcs and trenches	Insitu sampling (currents) and genomic identification & chem; particle counter for small particles - size fractions; Microbial assemblages; characterization and mapping ; taxonomy; role they're playing in larger ecology; bio/geo/chemical processes; bioactive compounds; subbottom profiling, coring. Consortia for development; Measurements of interaction between geology, biota, circulation area to target (Tow-Yos - sampling in vertical) Tonga Trench; deep dive mapping of gas hydrates; Standard plume techniques at Tonga Kermadec; location of chemical fluxes; biota; volumetrics; geologic signatures; sensing water column	Scientific: huge opportunity for fundamental discovery; Plate tectonics; Subduction factory; Tonga Kermadec; less than 2% been explored; mineral resources; bioactive compounds; health in the coastal zone; biotechnology; human health; (e.g. blooms); cause-effect; pollutants (tracking); Industry: seafood; biotech; genome mapping and modes of life, discovery of new antibiotics, invasive species; human health; biotoxins; untouched communities to understand equilibrium before disruption; trying to understand how they evolved thru time (e.g. duration of settlement in any one spot.); unique species w/ biochemical properties; effects of exploitation Outreach: origin of life; challenge for outreach; conceptual more than visual; education Regulatory: counteracting bioterrorism;
Ecosystem - Karst / Ring Depressions	Region: Great Lakes	Karst Features in Lake Huron (sinkholes); Ring Depressions (400-500 m across; 20-30m deep);	Collect info on spatial coverage, depth, dimensions, biology, chemistry, local flow pattern; How they formed, influence on distribution of benthic communities, sediments, contaminants, why not in other lakes	Scientific: Potential source of groundwater input, fish habitat, prehistoric culture; Most widespread feature on floor of North America's largest lake

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Lakes	Region: Great Lakes	Lake Biodiversity; Need to recharge all of the component areas of the lake systems;	Bio / Geo / chemical processes; Community structures & compositions; Species Diversity - looking for new species; (3 African Great Lakes); Rapid Assessment survey; Collection of long term Sediment cores; Geo-thermal Vents Systems; Describe landscape census; Looking for midwater scatters; Multibeam survey; Physical Ocean Sampling; Natural History Survey; Investigate use of streams for spawning; Ecosystems approach to water quality; Examine revival of species, Pollutants	Scientific: Undiscovered areas of bottom; findings new species in Great Lakes Understanding the origin of species and of Great lakes; River run-off; linkages between estuaries and river fauna, biota; complexity issues unique to the freshwater Lakes systems we drink. Industry: Global Pressures on fresh water resources; Global issues and local pressures on fresh water resources; New Species; Bio-Technology; Pharmaceuticals; Fundamental Ecological Principles to Apply to Management; Outreach: Human connection to Water Resources; Public Health Regulations: Land use polices and water sheds;
Ecosystem - Shorelines to Ledges	Region: Atlantic South Gulf of Mexico Alaska West Coast	The Point region: why is it so productive? Shoreline erosion; Intertidal zone; Inner shelf; Ledges, West Coast continental shelf	Not well documented; Map and inventory areas; ID subsidence in LA; Gulf of Mexico; erosion rates; sedimentation; storm surge impacts; salt water intrusion; habitat distribution and loss; impact; invasive species; impacts on infrastructure; Document biodiversity and taxonomy; Identify and characterize potential fish habitats, ID ground water discharge, relationships between biology and geology; physical oceanography - water mass characteristics; invasive species; harmful algal blooms Document archeology; Benthics; baseline mapping (high resolution); habitat substrate; cables physical oceanography;	Scientific: Not documented; Remote nature (Alaska); Will add value to other studies; unique - meeting of three water currents (The Point); very productive; hurricane impact - coastal hazards such as erosion, rapid response to natural or man-made catastrophic events, paleoshorelines - coastal evolution; knowledge of substrate, benthos, habitats and relationships; Industry: huge potential for natural gas economics; sand and mineral resources; understanding fish habitats for Fisheries; biotechnology Outreach: public concern; "backyard" education; entire community, Regulatory: protection from storm surge; loss of wetlands and other habitats; Conservation: sustainability; rational decision; biggest info gap

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Shorelines to Ledges	Region: Caribbean Atlantic South West Coast	Knowledge of fisheries habitats; What are fish stocks and habitat on the Islamorada Hump (nominated as a MPA)? Connectivity of habitats on shelf and edge of shelf; trophodynamic study.	Collect information on distribution, taxonomy, abundance, condition, and diversity, determine productivity in reef systems, define critical path and corridors including eddies and bio-physical connections; Identify key areas that may need protection - "critical habitats"; due to Insufficient scale/depth; define critical path and corridors including eddies and bio-physical connections. ID connected habitats; extent of spawning areas; connection between reefs; sample; determine source; track history of fish; follow biologics to determine behavior; tagging studies; molecular data analysis.	Scientific: Classically important fishing areas; never been explored; Marine Protected Areas location & defining; functionality of MPAs; understanding of unknown - ecological systems; behaviors; understanding of energy flow; status/impact assessment; Industry: Ecotourism, recreation; Regulatory: Fisheries Management; Better ability to monitor impact of fishing and other disturbances for areas of protection; Target areas for research;
Ecosystem - Shorelines to Ledges	Region: Gulf of Mexico Atlantic North	Mississippi River outflow on habitats; Knowledge of near shore environments	Understand the impacts of Mississippi River outflow on habitats; ecosystems (and secondary fresh water input); Determine river influence on Gulf systems; bio/geo/chem; frontal zones; Inventory, characterize, and measure: habitats, bathymetry, Bio/Geo/Chem of shallow water processes near fronts - colds corals, Archeology of Biological / Geological / Chemical characteristics.	Scientific: bottom health; flux of nutrients; Outreach: public interest; science; education; Regulatory: coastal zone management; fisheries management; conservation; policy remediation; regulatory oversight of runoff quality;

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Shorelines to Ledges	Region: West Coast	Near shore habitat; Archeological paleoclimate area	Habitat on near shore (shelf and slope); Archeological paleoclimate area; targeted anthropogenic impacts; high definition visual surveys; look for arch. sites of previous civilization; look for deeper wrecks; understanding of flows of chemicals; ID fisheries; physical; current flow interactions; discover history influences; understanding margin marine boundary layer	Scientific: understand part of ocean directly most interact with & human impact; link of chemistry and biota; Outreach: reach new stakeholders; connection to public; Regulatory: conservation areas.
Ecosystem - Slopes	Region: Alaska Atlantic North	Continental Rise and the Outer Continental Shelf, right down to the Abyssal Floor Plain; Slopes (600 to 4000 ft); Study Transitional Areas Between Biogeographic Areas & deeper Shelf Slope Regions	Document biological communities and geologic history, Examine record of continental climate; Species distribution and ranges; species dynamics, tropic interaction, invasive, patterns; Not Documented	Scientific: Least studied part of the ocean; a place where the bigger tsunamis may be generated from slope edge slumps; Not Documented; Very little information available that is not broad scaled; what regulates them?

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Slopes	Region: Atlantic South Alaska	Shelf to slope transition area; complex habitats - reefs (outer shelf), deep coral banks,	Survey bottom; physical sampling of water column dynamics; biological survey; sampling structural data; describing wreck structure; wood samples from wrecks; corrosion analysis; sampling substrates, subsurface geology; site stabilization; covering and uncovering of wrecks; observe new species; species interactions/behavior; habitat utilization; network of sensors; multidiscipline surveys; fisheries; ID community structures; characterize content of entire water column; plan comprehensive multiyear surveys (expand MARMAP monitoring, NMFS); generate timeline	Scientific: New knowledge, better understanding; impact assessment; gas chemistry; ID new species; impact of cable laying; lack of knowledge of biodiversity; pharmaceutical interest (sponge communities) Industry: resource management; oil industry; Outreach: historical / educational use; Regulatory: industry - protection
Ecosystem - Slopes	Region Atlantic South	Explore shelf break - upper slope	Broad based exploration survey; ID intercomparisons; use moored arrays; satellite; airborne; LIDAR; drifters; Include shelf edge; reefs; hard bottoms; paleoshorelines; spawning locations and sediment traps; habitat based observation; turbidity transport; mineral exploration; gas and groundwater seeps; dedicated estuarine coastal vessel for education and training of next generation of oceanographers to establish program of data and sample collection - potentially re-outfit Ferrell for this purpose	Scientific: observation studies; baseline characterization of very productive areas for EFH; upwelling zones; potential for mass wasting; tsunami generation; chemosynthetic communities; fluid flow; evolution of continental margin; mapping low stand deposits; influence of Gulf Stream; Industry: recreational; fishery; tourism; Outreach: get students out to sea - lots of opportunities; relevant region - in our back yard; Regulatory: coastal erosion; fishery; MPA's; regulation of shipwrecks

Category	Workshop	Exploration Targets	Description	Benefits
Episodic Events	Region: Great Lakes Atlantic North Atlantic South Caribbean	Integration of discoveries with accountability, need basic research with applied science; Event driven Storms, Surface and Benthic storms; Blooms; Distribution of nutrients, biomass & current influences; Rare species events	Identify distribution of nutrients, biomass & current influences; Identify frequency, strength, intensity, impact, magnitude, compare & contrast	Scientific: Understanding coastal processes; synergy of impacts and mitigation; Regulatory: Important for coastal zone management; Industry: Social economic relevance; safety of life and property;
Episodic Events	Region: Gulf of Mexico	Hypoxia phenomenon; Loop and related currents to HAB formation	Origin; effects of hypoxia; Understanding of relationship of loop and related currents to HAB formation and other species that are not normally seen; discover mechanisms of transport that leads to formation and distribution	Industry: economics; recreation industry; impact industry (shrimp; oyster; and fishing); Outreach: human health issue
Episodic Events	Region: West Coast	Plate scale to mesoscale	Develop a Plate scale to mesoscale (gyre scale) observatory for long-term understanding of episodic events; measure absorption of CO ₂ ; requires a thorough mapping effort; collaborative effort; provides new ways to do oceanography; understanding fluid flux productivity of subduction zones; sources of interplanetary life	Scientific: supports a scientific CNN; opens temporal domain; resolves limitations of surface vessels; new paradigm of sampling in time and space; Outreach: interactive telescope into inner space; internationally unique

Category	Workshop	Exploration Targets	Description	Benefits
Extreme Environments - Vents, Seeps & Volcanoes (See also: Ecosystem - Extreme environments - Vents, Seeps, and Volcanoes)	Region: Great Lakes Hawaii Caribbean	Unknown hydrothermal features in lake systems; Need high resolution spatial & temporal zooplankton measurements over space & time; classification needed; Unknown Seeps/ Non-Oxygen Environments - evolution in isolation, inter-lake comparisons, genetics in large time scales Active volcanism; Sample and map new hot spots; fundamental understanding; Unknown knowledge of micro-organisms in the deep sub-bottom	ID chemistry, microbiology, nutrient dynamics from high resolution surveys. General mapping; access naval data; Airborne geochemical, seismic; and passive acoustics measurements; track plumes and trace elements from plumes from air; set up listening arrays; locate features using mapping technology; Investigate Loihi, Samoa, Louisville Ridge; sampling deep mantle plume; sample volcanic edifice edge of seafloor; seafloor biosphere needed.	Scientific: Unique and unknown evolutionary aspects of microbiology in fresh water lakes, bioremediation; Major component of the food web depends on fresh water body; Fundamentals of evolution of life, island biogeography; extremophiles, Identify sites and new life in sustaining processes- possible origin of life answers, composition, geological properties, biological properties, chemical properties and flux, plume characteristics Industry: oceanographic power source for sensors; minerals and biotech; Outreach: Lots of public interest, education and conservation.
Geology & Geomorphology	Region: Alaska	Glaciers: origin in Bering Sea; Discover characteristics of environment created or released from glaciers; Plate Boundary - Strike Slip System; Documenting climate variability	Identify and characterize these environments, explore, collect and measure features; Map and perform water column survey, identify and characterize biota; Neotectonics; Areas of seeps; compare w/ other plate boundaries; Areas of large earthquakes and sediment slides; 500 million year record of global climate; Need to examine it to look for variability	Scientific: Not well understood; fresh water inputs to ocean; consequences of rapid glacier retreat; Not well documented; Is human activity changing the Gulf of Alaska; Industry: Possible coldwater petroleum seeps

Category	Workshop	Exploration Targets	Description	Benefits
Geology & Geomorphology	Region: Atlantic North Atlantic South Caribbean Hawaii	Discover and mapping of paleoshorelines and relict reefs (tend to be fish habitats); Lack of sub-bottom mapping of sea floor sediments Holocene (last 10,000 yrs) Not well documented; Knowledge of Physical Processes related to geomorphology	Map; ID; characterize shorelines and reefs; develop baselines for geology, biology, water quality; ID and characterize sediments; ID historical sea level information, find wave notches, ledges, other geomorphological features, lava tubes and marine caves; ID mass-gravity movement, turbidity flows, hydrate beds, slope instability; conduct chemical analysis	Scientific: understand sea level and paleoclimate changes, essential to understanding history; foundation for essential fish habitat, sea floor habitats, beach deposits, and anthropogenic factors. Understand canyon formation processes, safety (geo-hazards) habitats, Not well documented
Geology & Geomorphology	Region: Gulf of Mexico	Bottom boundary dynamics; Knowledge of sub-bottom characteristics; Knowledge of rivers of warm; dense brine from salt province; Knowledge of slope stability	ID and map distribution and process details of fluid and gas expulsions; carbonate formations; and seismic activity; Determine morphology; composition; dynamics; Heat flow measurements; mapping; origin; effects; Inventory and characterize debris floats; gas; slopes; faults; gas hydrates; mud flows; date features	Scientific: tipper for hydrocarbons (energy resources); fish habitat; geohazards; climate/carbon cycle; ID chemosynthetic communities and controls on the fluid and gas expulsion; modifications on habitats; Industry: resource management; identifier of hydrate deposits and industry zones; Origin and effects of the Gulf salt province; Oil and gas exploration and production.
Geology & Geomorphology	Region: Gulf of Mexico Great Lakes	Knowledge of Mega-furrows	Determine origin; physical characterization over time; size; shape; currents	Scientific: recently identified in Gulf; impact on currents; don't know where sediment goes from erosion; habitat issues

Category	Workshop	Exploration Targets	Description	Benefits
High Resolution Bathymetry	Region: Alaska Great lakes Hawaii	Not mapped; not enough resolution in existing maps; Complete Bottom survey of Great Lakes not done - Shallow water mapping; Extension of Coastal Estuaries & Wetlands; Understanding substrates to particle size; Near shore fossil coral reefs (Chicago and similar environments); east-end of Lake Superior; Mid-Lake Reefs; Mid-Lake ridge through Lake Huron; Lake Champlain; Foundation for exploration; Need more accurate charts of Pacific seamounts and banks.	Conduct high resolution hydrographic, bathymetric and tidal data survey - mean low and high water with multibeam and side scan sonar; Document navigation hazards, and biota	Scientific: Not mapped; not enough resolution in existing maps; Tidal data to establish boundaries; Understand how sea data changes with events; Unknown biota; Discover new features and location; Fisheries; Cultural Heritage (Climate history, Lake Levels, down stream mouths & Inundated cultures); Identifying Exploration Targets; Road maps for research; Inferring Lake processes boundary conditions; insight into deep water circulation & sedimentation patterns; Industry: Arctic path for shipping; Navigation
High Resolution Bathymetry	Region: Gulf of Mexico	Mapping of the Gulf, Need framework for further exploration and research; Mapping between known topographic features	Bathymetry surveys with multibeam and side scan sonar	Scientific: Unknown regions: utility of dataset once it is developed; not done in many areas; slope is an important habitat; use bathymetry to find essential fish habitat (seasonality); Industry: new discoveries; interactive website; discovery of new resources (fishery; bioproducts; chemical; oil); Outreach: education - tapping into grad students; incorporate data sets into curricula such as GIS classes

Category	Workshop	Exploration Targets	Description	Benefits
Human Impacts	Region: Alaska Gulf of Mexico Hawaii	Identify Hazard Dumps at sea; Potential threat site location; Need safe nuclear waste disposal site.	Location of site of potential threat to the environment and processes near the sites; wrecks; marine debris; dump sites; abandoned platforms; Determine location and chemistry of material; Characterize these sites	Scientific: knowledge of impact of materials on ecosystems health; Outreach: much public interest; Industry: Potential biohazard, fisheries; Regulatory: conservation; management; safety; remediation; policy; regulation; enforcement; pollution impact; long-term anthropogenic impacts; safety
Human Impacts	Region: Caribbean Hawaii Atlantic North	Impacts of Pollution; Pollution and marine pathogens; Understanding biomagnification of pollutants and toxins in the marine food web (similar to large pelagic); Knowledge of impact of Fishing on Ocean Regions	Determine anthropogenic impacts on marine mammals and their habitats from ships, blast fishing, Military Ops, Energy Refineries and energy conversion activities; broad area surveys, tracking mammals; Use pathogen count as a marker; quantifying toxins;	Scientific: may resolve competition for resources and habitat loss and degradation; understanding impact on ecosystems; fishing; Archeological Impacts; History of technology; Outreach: Health and education; Regulatory: MMPA, EPA dumping at sea management; Health of Benthic Habitat; CoML; Fisheries management; unknown areas of deep benthic fish populations.
Human Impacts	Region: Gulf of Mexico	Anthropogenic noise	Monitoring natural (biological and geological) and anthropogenic noise; effects of human induced noises on biota; natural noise	Scientific: natural noise can be used as a measurement of health - can be used as a proxy for measurement of animal health

Category	Workshop	Exploration Targets	Description	Benefits
Marine Conservation	Region: Alaska Atlantic South	Essential Fish Habitat; Need knowledge of Recruitment and spillover mechanisms in Marine Protected Area networks; Characterize "deep" Marine Protected Areas (including deep reefs)	Map and inventory benthic habitats to gain understanding impacts of essential fish habitats; candidate areas of protection; Map; ID; characterize; develop baselines for geology, biology, water quality; oceanographic parameters; need to explore and ID ecologically, info on spawning, eggs, larvae spillover and transport systems etc.; behavior of early life history stages that affect recruitment. ID candidate Marine Protected Areas; Location & dynamics of archeological sites of historical significance through the use of: vessel explorations; data mining; manned observatory; fixed sensors and arrays; ID biota that needs protection	Scientific: little is known about proposed marine reserve regions - most are deep regions, greater than 50m; Understand role in supporting ecosystem spawning Regulatory: huge management implications; conservation; info for enforcement; ensure knowledge of the constituents that need protection; management and policy Outreach: SAFMC (South Atlantic Fishery Management Council) purposes; determining potential recreational interests; public affinity; Industry: Possible biotech implications
Marine Conservation	Region: Atlantic South	Oculina Banks; Effect of closure and 10 yr limit on no fishing;	ID; characterize recruitment and spillover mechanisms; artificial reef impact; comparison with existing baseline studies	Scientific: only Marine Protected Area in S. Atlantic Bight where fishing is not allowed, huge oculina coral region, deep reef at 300ft, oculina destroyed by shrimp trawling and scallop dredging, efforts to reseed right now, will coral self recruit?, unique habitat, assessment of restoration techniques, still don't know a lot about it, no research funds provided to demonstrate effectiveness of Marine Protected Area in restoring corals and fishes

Category	Workshop	Exploration Targets	Description	Benefits
Marine Microorganisms	Region: Alaska Atlantic South Caribbean Hawaii	Knowledge of Microbes in the Bering and Chukchi Sea and other seas; Microscopic Interfaces; Microbial roles in ecosystems; They are the most abundant organisms in the marine environment; control biogeochemical cycling;	Microbiology and micro-zooplankton sampling of abundant and important microbes and micro-zooplankton; Explore unknown micro- / nano-environment; Characterize it including Information on microscopic interfaces of chemistry, microbiology (liquid-solid interface)	Scientific: Gain knowledge of ecosystem health; Understand long-term variability. Not well understood; Need fine-scale knowledge; These organisms likely play critical role in function of ecosystem; Understand changes affecting ocean productivity; Understand role in producing biocompounds and enhancing biodiversity; Industry: Impact on Ecosystems and human & habitat health; biotech applications
Marine Microorganisms	Region: Hawaii	Marine parasite lifecycles; Marine viruses	Documenting parasites; life cycle; primary and secondary hosts	Scientific: Knowledge of the effects on carbon and phosphorus cycling.
Marine Organisms	Region: Alaska Caribbean Great Lakes Gulf of Mexico Atlantic North	Migration patterns for high latitude organisms; How Animals use Vision & Light to Orient Themselves in the Water; Populations in flux; Biological Transitions Zones; Understand exotic invasive species; Understand cross Gulf migratory birds; Distribution migration & abundance of Gelatinous plankton	Collect data to understand the vulnerability of birds and mammals; document visible communication; Linkages of rivers estuaries and basin; Use of streams for spawning; Ecosystems approach to water quality; Examine revival of species, Pollutants; Identify organisms transitions zones; mapping of systems; Understand invasive species success or decline, impact, taxonomy, and genetics; Contribute to migratory birds database (can add bird migration to other studies)	Scientific: Support for designation of critical habitats; Know very little, spin-off potential for other technologies, dictate habitat utilization, mating; helps identify global climate changes, fish species mobility, numbers; Ranges decline of organisms; Changes in biodiversity; ecological impacts; Pelagic plankton are the dominant Biomass; Fisheries Impact, Evolution Knowledge; Outreach: education effort; Industry: economics; resource management

Category	Workshop	Exploration Targets	Description	Benefits
Marine Organisms	Region: Atlantic South Great lakes Hawaii	FISH: Expanding fisheries (exploitation of new species), Distribution of marine geographic endemics; Abyssal Fish (> 50m); Evolutionary Biology; evolution in isolation, inter-lake comparisons, genetics in large time scales; Genetic connectivity of Gulf of Mexico ecosystems; Understand specimen migrations through Hawaii Arch.	Establish fishery dependent sampling & fishery independent sampling baseline information such as abundance, growth rates, reproduction, etc.; getting samples from landings reproduction, etc.; conduct independent surveys; Targeted tagging and photo ID; Otolith elemental fingerprinting Document taxonomy and life history; Many of the best studied groups have pelagic larval distributions - corals, shallow-water tropical marine fishes; may give much better understanding of evolution and extinction. impact of invasive species, spawning (where & how especially in winter season), character displacement behavior; genomic mapping	Scientific: Management of newly exploited species; new pharmaceutical compounds such as antibiotics; Know very little, gene flow problem, recruitment problem, invasive species problems, displacement behavior; knowing mating game, life history, learning more about diporeia decline; island biogeography; Recruitment patterns; larval dispersal, distribution, and stages; Characterizing reefs; Industry: sustainable fisheries; bioprospecting Outreach: great educational opportunities; power plants (e.g. zebra mussel issue), municipal water plants, carbon cycling; huge public concern; stewardship of fisheries; Regulatory: sustainable fisheries; water quality and contaminants; marine bioconservation
Marine Organisms	Region: Atlantic South Caribbean Great Lakes	Productivity Knowledge: Seasonality of upwelling and associated spawning and larval distribution; Habitats of spawning aggregations of fish; Connection of separated populations (esp. fish)	Map locations of upwelling and gyres; measure productivity; sample plankton; measure vertical flux to sea floor; physical/chemical water column characteristics; Document distribution, taxonomy, condition, and life history; determine mechanisms underlying Fish aggregations; How Habitats impact each other.	Scientific: to understand importance of upwelling, explain or predict recruitment to fisheries, effects on estuarine systems, life history; unique habitats and locations; larval transport pathways; understanding of dynamics of fisheries and ecosystems; Regulatory: many areas over fished; conservation and management

Category	Workshop	Exploration Targets	Description	Benefits
Marine Organisms	Region: Caribbean Gulf of Mexico Hawaii West Coast	Marine Mammals: Distribution movement, orientation, and abundance of Deep Diving and Long Range Marine Mammals; Food source/distribution linkage (includes vertical migrates); migration patterns; understand habitats of large pelagic animals; Identify Coelacanth, giant squid, megamouth (obscure, unknown animals) ID the guideposts in the ocean. ID how populations succeed; behavior patterns; interactions with ocean structures; use of habitat; range and navigation	Observe visual behavior, environment, and habitat through use of all senses; Collect and document the understanding distribution and migration patterns of marine mammals; Charismatic megafauna (whales; manta rays; sea turtles; dolphins; whale sharks; etc); response to anthropogenic impacts (noise; other pollution); location; reproduction; general life history questions; genetics; Collect images; Tagging and satellite data comparisons for behavior patterns; acoustic subsurface surveys (foraging) by attaching instruments to animal movements; interaction with benthos, linking foraging with physical environment	Scientific: Discover new species; Unknown distributions; global entities and don't know much about them; reproduction; genetics; bioactive compounds; understanding role of compounds in nature; Industry: resource management; bioproducts; public disclosure of data; Outreach: fascinating to public; huge outreach component; education Regulatory: Conservation and management; some species are endangered; conservation; International policy cooperation.
Marine Organisms	Region: Caribbean Hawaii Atlantic North	All taxa biodiversity inventory; Marine biodiversity - inventory from Hawaii Islands - Deep Marine (>200m - ~6500m or beyond); Ecosystem Engineers and foundation species (corals, tile fish), Knowledge of novel feeding relationships	Species inventory; Identify chemical characteristics, abundance, and diversity; Discover and inventory new living resources (non-fishery) with commercial potential, target areas and habitats not well documented; coordinated Hawaiian Island. Ridge inventory; establish patterns;	Scientific: Preservation of species; Discover new species; survivability and genetic and chemical diversity; bioactive compounds, new bioproducts; understanding role of compounds in nature; census of marine life; Unknown feeding relationships could be major sources of nutrition; discover new linkages; Industry - bioproducts; public disclosure of data; Outreach: media coverage; understanding wide environments; Regulatory: management.

Category	Workshop	Exploration Targets	Description	Benefits
Ocean Resources - Bioprospecting	Region: Atlantic North Atlantic South Caribbean	Discover potential Bioprospecting targets	Charleston Bump (mg); Blake Plateau (gas hydrates; sand); inner shelf; collect samples of marine organisms; water samples; sediment samples; collect DNA from marine organisms; ID application of new micro/macro organisms on drug discoveries & other industrial products;	Scientific: new information; resource identification; oceanographic processes; Industry: tourism; recreation; New industrial processes and biotech products; Outreach: conservation of resources; Regulatory: local governments; coastal zone managers
Ocean Resources - Energy & Minerals	Region: Alaska Atlantic North Atlantic South Gulf of Mexico Hawaii West Coast	Knowledge of ocean renewable resources: Gas Hydrates and provinces, minerals deposits; Discovery of deep sea minerals; Develop detailed baseline knowledge of candidate currents/locations; crustal processes	Document interaction w/ ocean; Identify and characterize communities associated with them; Survey, Map distribution and location. Charleston Bump (mg); Blake Plateau (gas hydrates, sand); inner shelf; manganese nodules; phosphorites; sand resources for beach nourishment; heavy metals; Crustal processes that affect fluid flow; determination of location and volume of hydrate resources; classification; chemistry; fluid flow; subduction zone; hydrothermal processes; microbial populations and dynamics ID classification, fluid flow, and chemistry; ID climate impacts, slope stability	Scientific: undiscovered energy and minerals; impact on environment (climate; carbon cycle); geohazard/sea floor stability; means by which earth cools itself; how fluids are forced from crust; Global climate impact, Industry: potential natural resource; cable laying process; Methane deposits are two orders or more (is it recoverable?) than elsewhere in the world; more methane than other fossil fuels; tourism, recreation; Outreach: conservation; safety- Tsunami awareness and bottom mounted cables; Regulatory: local governments; coastal zone managers, shoreline protection

Category	Workshop	Exploration Targets	Description	Benefits
Pelagic Environment	Region: Atlantic North Atlantic South Gulf of Mexico Great Lakes West Coast	Mid Water Exploration: Knowledge of shelf-wide water column (physical, biological, chemical); Need constant monitoring of Pelagic community. Knowledge of "Life in one cubic meter of water" in surrounding waters; What is in the pelagic realm to conserve and exploit.	Characterization of organisms, circulation; nutrient distributions; nutrient flux; mixing; recruitment dynamics; jellyfish; conduct water column sampling; time-series monitoring; establish buoy networks, or an upward looking devices to monitor water column and seasonal change, transition rates, feeding rates etc.; collect ground truth data, compare between different biota. Characterize food web; link between upper water, slope water, and benthic water; how the midwater functions in this role; evolutionary relationships;	Scientific: Unknown interactions in the water column, "Largest Ecosystem and biomass on the planet"; knowledge of spawning and distribution patterns, baseline data for rapid response to blooms; new biota; micro level of how oceans work; Little known about larval distributions, taxonomy; important to carbon cycle; lots of species unknown to science; unknown contribution to food web; relation with upper water community; link to climate change; discovery is guaranteed. Industry: HAB response; resources management; applications of tech.; Outreach: tourism, recreation, fishing, toxicology, pharmaceutical, biowarfare; public information via media. Regulatory: dumping regulations.
Pelagic Environments	Region: West Coast	Use of pelagic and benthic environments by economically/ecologically important species; by Rare Species	Life history; migration patterns; habitat; population; distribution and abundance; environmental properties; Track location of critter; Beacon to uniquely ID individual; Attach Critter Cam; fronts/eddies - use remote sensing to ID areas; Listen and observe sounds; LIDAR to monitor; observe; track fish	Scientific: basic knowledge of behavior; migrations and how they use their environment; resource management; little known about them; Industry: sport fishing; small business; they engender energy and excitement from public; Regulatory: need to know more to protect them
Pelagic Environment	Region: West Coast	Euphotic zone productivity, Harmful Algal Bloom (HAB) causes;	Collect data on HAB triggers, understand productivity of ocean in euphotic zone; understanding life stages of organisms; discover new members; <20 microns (includes viruses; parasites); spatial structures (scales); need balance equation	Scientific: HABs; understanding health of oceans

Category	Workshop	Exploration Targets	Description	Benefits
Sound in the Ocean	Region: Alaska Atlantic South Hawaii	Characterize and inventory naturally occurring sounds	Listen to seismic acoustics, fauna acoustics, Marine mammals, and fish; Use acoustics to determine migration paths	Scientific: New way to look at ocean; break into new applications of acoustics.

4.4 Partnerships

Integrated in the identification of exploration needs was an opportunity for the workshop participants list potential partners in exploration pursuits. It should be noted that the majority of the attendees represented academic and government stakeholders with less representation from commercial or other private organizations. As a result, the potential commercial partners identified during the workshops probably do not reflect the scope of potential partners who are likely to be engaged in the ocean exploration process.

Regional participants were given guidance in identifying partners including categories adapted from the *Frontier Report* in order to facilitate summarizing the overall regional results. The categories included government, academic, industry and non-governmental organizations (NGOs).

Participant recommendations for potential partners were divided into a set of “standard partners” and other need-specific partners. As discussed previously, the standard partners represented recurring organizations with a common interest in the region’s exploration activities. These partners are listed at the beginning of each set of regional results in Section 3.4. Need-specific partners were identified based on their ability to provide unique support specific to the associated need. These partners are included within the contents of the regional results in Section 3.4.

Government agencies represented the largest category of potential partners. These partners represent agencies that assist in seeking knowledge about how the oceans function and to support their missions of national security, transportation, and the conservation and management of natural resources. Agencies recorded in the greatest frequency included NOAA and its components, NSF, Navy, Coast Guard, USGS, Mineral Management Service (MMS) and EPA. Foreign governments cited in order of highest frequency included: Canada, Japan, Russia, Mexico, Cuba, and France.

NGOs accounted for a quarter of the potential partnerships. These organizations are typically interested in a broad spectrum of ocean interests including conservation,

protection, education, entertainment, and research. Organizations frequently identified by the workshop participants include aquariums, museums (Smithsonian, Bishop), recreation groups and associations (fishing, diving and other local groups), and oceanographic entities such as the Harbor Branch Oceanographic Institution and the Woods Hole Oceanographic Institution.

Industry comprised a fifth of the potential partners recommended by the workshop participants. Industry sectors are expected to seek knowledge to support commercial activities such as fishing, energy and mineral extraction, pharmaceuticals; commercial fishing, energy (gas & oil) and biotechnology were identified.

Academic institutions concerned with oceanographic research were well represented in each region as potential partners. International universities were included for activities in the Bahamas and Canada.

A limited number of media organizations were specifically identified (e.g., the Discovery Channel and the British Broadcasting Company) but the participants recognized the media in general as important partners in exploration activities. These relationships are certain to expand with an increasing emphasis on ocean exploration outreach.

4.5 Issues

As stated in Section 2, the workshop process was designed to collect ocean exploration needs and associated approaches for satisfying those needs from each of the participating regions. During the conduct of the workshops, discussion among participants often migrated to issues related to the OE program that were not representative of specific ocean exploration needs or approaches. Several issues common to multiple workshops are included in this section to ensure their inclusion within this report and to recognize the contribution of these discussions to the value of the workshops.

- *Data Management.* The issue of managing ocean exploration data was raised at each of the eight regional workshops. Participants were generally concerned about the lack of standardized data management policies and procedures throughout the oceanographic community. Recognizing the need for managing exploration data and its value to a broad community of public and private stakeholders, participants were

equally concerned about the availability of resources within the government to support a viable OE data management process. Several attendees noted that principal investigators tend to be apprehensive over timely release of data to the public due to the potential for competing interests—particularly well-funded commercial entities—to exploit these data at their expense. There was a common recognition of the importance for OE to develop standardized, flexible data management policies and procedures and integrate them into the OE program.

- *Existing Information and Data Mining.* Workshop participants recognized the likely existence of many oceanographic databases that could expand the scientific knowledge baseline if they were accessible. Many databases are privately owned by industry due to their commercial and competitive value. An example is in the Gulf of Mexico region, where industry databases of high-resolution bathymetry and sub-bottom profiles are known to exist. Without access to these data, explorers in this region working in the public interest have been obliged to recreate these data at considerable expense. The workshop attendees also noted the broader issue of the need for data mining services that could access as many existing public and private databases as possible. There was general agreement that these services were beyond the scope of the OE program but should be addressed by entities charged with the responsibility for environmental data and information services. Participants encouraged the current OE practice of working with a large number of collaborators in order to create strategic partnerships that could enable greater access to other data sources.
- *Definition of Ocean Exploration.* Despite the guidance contained in the *Frontier* Report and the OE Announcements of Opportunity, participants held varying definitions of ocean exploration and the scope of activities that they thought should be sponsored by the OE program. Attendees sought to clearly separate exploration from basic research, and coastal zone exploration from ocean exploration. With guidance provided by OE leadership at each of the workshops, the participants generally recognized that concise and complete definitions were difficult to achieve, and that the potential reach of exploration activities is defined in part by the level of resources available to the OE program. It was generally agreed that continued exposure of the OE program and its activities would lead to a greater understanding of the scope of the program among the various exploration stakeholders.
- *Outreach.* Many workshop participants sought greater time during the process for OE program outreach. The general consensus among workshop participants was that outreach would be critical to the future success of the OE program. Attendees were pleased to learn that OE had adopted an internal policy of allocating 10 percent of its annual budget for education and outreach functions. Many participants felt that current outreach efforts should be expanded, and that the general public residing in areas removed from the oceans—where the connections between the oceans and the daily impact on their livelihood are not as apparent—should be a specific outreach target. Several participants recommended that OE host a national conference with a focus on ocean exploration outreach to the public.

- *Maritime Heritage.* At each of the eight regional workshops, attendees representing the marine archeology community expressed support for the OE program emphasis on finding and preserving maritime heritage resources and sought additional methods for protecting submerged historical sites from exploitation. Submerged historical findings are a great way to stimulate public interest, but once information on these findings is made public these sites often suffer from uncontrolled and unregulated access. It was suggested that the OE program could participate in sponsoring an educational campaign that would focus on maritime preservation issues such as responsible shipwreck diving by recreational and commercial divers.
- *Local Knowledge.* In the Alaska and West Coast regional workshops, the use of traditional, local knowledge as a component of ocean exploration was emphasized as an idea that warrants further examination. Participants at these workshops noted that indigenous populations such as the Inuit and Native Americans might have considerable oceanographic knowledge that has been overlooked for many years. It was suggested that OE examine practical ways to make use of these resources through creative collaboration and outreach efforts.
- *Taxonomic Expertise.* In several workshops, the need for resources with taxonomic expertise was identified as a critical issue. Participants generally felt that there is a decreasing pool of these experts within the oceanographic community due to the inability of individuals to center their career aspirations in such a narrowly focused field. Many expressed the concern that the taxonomic baseline was becoming diluted and that marine organisms are increasingly being assigned inaccurate taxonomy, making it difficult to characterize new discoveries. At one workshop, the attendees decided that this issue was important enough that the government should consider establishing a professional series for taxonomic specialists to ensure an appropriate emphasis on the need.

Appendix A: Workshop Attendees

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Endnotes

¹ *Discovering Earth's Final Frontier: A U.S. Strategy for Ocean Exploration*. Report of the President's Panel on Ocean Exploration, University Corporation for Atmospheric Research, October 10, 2000.

² *Ocean Exploration Program Strategic Framework*. National Oceanic and Atmospheric Administration, Office of Ocean Exploration, Mitretek Systems, Inc., January 24, 2002.

³ Gudes, S. B., Testimony before the House Resources Committee, Subcommittee on Fisheries Conservation, Wildlife, and Oceans; and the House Science Committee, Subcommittee on Environment, Technology and Standards and Subcommittee on Research, United States House of Representatives, July 12, 2001.

⁴ Senior NURC and NMS personnel responsible for nominating participants and identifying local on-site coordinators included Andrew Shepard, NURC at the Univ. of North Carolina, Wilmington; Ivar Babb, NURC at the Univ. of Connecticut; Andrew DeVogelaere, Monterey Bay National Marine Sanctuary; Alex Malahoff, NURC at the Hawaii Undersea Research Laboratory; and Ray Highsmith, NURC at the Univ. of Alaska, Fairbanks.

⁵ This element was initially designed as a relative measure of cost, and was modified at the suggestion of participants during the Caribbean region workshop. The measure of feasibility incorporated a general assessment of all risks related to a particular approach and was recorded as either high, moderate, or low.

⁶ Use of the "standard package" and "standard partners" terminology was not integrated into the workshop process until the Hawaii workshop. To preserve consistency in the presentation of information in Section 3.2, related data from the Caribbean and Gulf of Mexico workshops were examined and recurring items from these two regions were extracted to produce entries for the standard packages and partners. Participants at these two workshops did not produce these entries as a separate product during the process.

⁷ *Op. Cit.*, *Discovering Earth's Final Frontier: A U.S. Strategy for Ocean Exploration*, pp 12-20.

⁸ *Ibid.*, p. 31.

⁹ *Ibid.*, pp 21-22.

